THE UNIVERSITY OF ALBERTA

THE MEASUREMENT OF MANUAL-DIGITAL FINE MOTOR CONTROL

BY

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF EDUCATION

DEPARTMENT OF ELEMENTARY EDUCATION
EDMONTON, ALBERTA

OCTOBER, 1967

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled MEASUREMENT OF DIGITAL FINE MOTOR CONTROL submitted by Emma Flint in partial fulfilment of the requirements for the degree of Master of Education.

ABSTRACT

This study was undertaken to investigate the need for and practicability of an additional technique to be used in the assessment of the development of children who are entering school for the first time. It was felt that the area of fine motor coordination, as tested by the "copying test" that is usually administered, was not being broken down into the discrete component processes which compose the complex that goes into the execution of such a task. As a result there was no deliniation of the precise area to which remediation could be directed, when underdevelopment was detected.

A device was designed and constructed that would translate into graphs the pressure patterns exerted during the execution of certain written tasks. These tasks were repeated with eyes open and eyes closed, using dominant and non-dominant hand in turn.

The sample used was composed to two groups: fifty-four adults and fifty-eight nursery school children.

It was found that the scores of the nursery school children were significantly different when eyes were open and when eyes were closed. It was also found that at maturity (as evidenced by the adults) the patterns of performance differed from those of the children in a manner that indicated the direction in which development tends to proceed.

The influence of laterality, practice and visual monitoring on a graphomotor act was also visible from the scores.

A suggestion of the amount of transfer of training from previous experience that a child brings to the writing process was contained in the

results of this study. The conclusion of previous studies regarding the specificity of motor skills was also confirmed.

Coordinated processes were found to be operating on the level of development of the weakest of their component processes. It therefore appears that any task that involves a complex of processes cannot validly be used for diagnosis of what is necessary for remediation. For diagnostic purposes it is essential to determine the state of each of the components as well as the state of the ability to coordinate them.

The implication for the teaching of reading reinforces the findings of other researchers: developmental readiness must be assessed and if it is underdeveloped, it must have specific techniques adapted to the specific needs of the individual directed toward its development. This specificity can only be obtained through specificity in testing procedures.

ACKNOWLEDGEMENTS

The writer wishes to express her sincere appreciation to the following persons for their assistance during the development of this thesis:

Dr. Dorothy Lampard for her consistent guidance, support and encouragement;

Mr. D. Sawada and Dr. Patricia Lane for their assistance with the statistical analysis of the data and its formulation into tables;

The other members of the Committee for the valuable suggestions they offered;

The Nursery School personnel whose generous cooperation made the children of this study available to the researcher;

The adult volunteers who took time from their own work to assist with the study by forming the adult sample.

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CHAPTER I

THE PROBLEM

Introduction and Background of the Study

The ability of a child to make a "passmark" on the "copying" section that constitutes the visual-motor skills subtest of the test battery to which he is subjected upon school entry, is considered predictive of his ability to benefit from instruction in writing-drawing skills. Since these skills have also long been used to reinforce learning (Fernald, 1921), it has also been considered valid to include the score from this subtest in the total which is used to predict the ability of the child to benefit from the complete programme offered in first grade. Thus, the <u>Detroit Beginning First-Grade Intelligence Test</u> (Engel and Baker, 1935), widely used on this continent, allots almost 10 per cent to this one subtest, and rates it more highly than those which evaluate visual discrimination, the ability to hold directions in mind, the knowledge of essential attributes and the knowledge of numbers. The <u>Metropolitan Readiness Tests</u> (Hildreth and Griffiths, 1950) also allot 10 per cent to the same area and comment in the manual of directions.

> <u>Test 6. Copying</u>. Test 6 measures a combination of visual perception and motor control such as that required in learning to write. This type of test has proved to be diagnostic of mental maturity as well as physical development in young children.

Diagnosis, however, can only be considered valuable when it can be used as a basis for remediation in those cases in which performance is found to be below the desired level. Unsatisfactory performance may

be due to one or more of several contributary causes.

The concept that is being investigated may be absent from a child's repertoire as the result of a deficiency either in mental endowment or in opportunity and experience. On the other hand, the concept may have been fully enough developed, but the required response may have been inhibited by problems of visual acuity in the reception of the stimulus or in the production of the response. Further, both the mental concept and visual acuity may have been developed to a level that would have made them adequate in any other medium, but the presence of perceptual problems may have prevented their utilization in the context of the particular situation in which the test took place. Underdeveloped motor control, too, can prevent a response from being of acceptable quality, despite normal maturity in cognition, perception or vision.

To further complicate the situation, it is possible for all component processes necessary to a response to have matured while the ability to coordinate them remains unperfected through lack of practice or undermined by the influence of some inhibiting factor.

The examination of visual-motor skills through the use of a simple "Copying Test", yields, therefore, a bare minimum of useful information. It discloses merely whether a child can, or cannot, successfully carry out the task, but it does not indicate the areas in which weakness or underdevelopment are making the task difficult or impossible for him. For the purposes of remediation, much greater precision and specificity is required in diagnostic procedures.

Research into the nature of the learning process has demonstrated that it is a composite of many skills that have themselves been learned

and developed and that each of these skills is also not a unitary process, but is, in its turn, dependent upon learnings and maturational factors. Diagnosis is, as a result, required to be directed to increasingly overlaid, but basic and discrete areas that compose the underlying structures of what eventually becomes the individual's developmental level. This level constitutes the potential for further learning, and it is this level that has in the past been assessed for the purpose of deciding upon the "readiness" of a child to benefit from any given programme of instruction. When that readiness is revealed as inadequate, the reason for its inadequacy must be determined through the use of specific instruments designed to evaluate the development of the underlying factors, complex and interwoven as they may be. Only when accurate identification and isolation of problem areas has been completed, can remediation be directed specifically at them.

The characteristics of the more recently introduced testing batteries indicate that concerned professionals are attempting to meet the demands of the testing situation in which the pre-school child is involved. Not only are the newer batteries expanded and refined, when compared with the ones in previous use (de Hirsch, 1966), not only do they attempt to base prediction on a greater body of pertinent data, but theoretical constructs, are through them, now being translated into practical applications, so that differential diagnosis of assests and deficiencies is being attempted. The Illinois Test of Psycholinguistic Abilities (McCarthy and Kirk, 1961), is being used to assess the levels of concept development by analysis of decoding and encoding abilities in visual, auditory and motor media. Opthalmologists and optometrists

are availing themselves of an ever increasing volume of techniques and instruments by which the efficiency of visual function of very young children can be evaluated so that remedial orthoptics, refractive prescriptions or surgical procedures may be employed at the earliest indication of disability. Specific tests to detect the presence of developmental problems in visual perception have been devised and programmes have been designed to overcome them (Frostig, 1963).

The area of performance commonly designated as "eye-hand coordination" has, however, at the pre-school level, yet to be provided with such techniques of differentiation. There is still no simple method of discovering whether manual-digital fine motor control has reached an adequate stage of development for basic writing tasks, or whether it is the process of coordinating the two motor functions (visual and manual-digital) that is underdeveloped although each of the components are mature in themselves.

Purpose of the Study

Precise assessment of fine motor control has been made practicable through the use of polygraphs and of other massive, complicated, expensive electronic equipment that requires the services of highly trained personnel to operate and maintain. This limits such assessment to use for medical or similar research purposes. Mass screening devices, however, need not have the precision that is essential to medical or refined research diagnosis, since it is assumed that the performance of the majority of children falls within the normal range. Any suggestion of gross abnormality disclosed by mass screening procedures is interpreted

as signifying the need for immediate referral to specialized professionals for a more precise and accurate diagnosis.

A simple, portable, inexpensive mass screening device would, however, do more than give timely warning of the need to consult neurologists or other specialists. By specifying the area of under-development in less severe cases, it would also make possible the provision of developmental activities to foster maximum progress toward normalcy. A beginning would then have been made in extending the benefits of differential diagnosis for prediction and remediation, to the field of "eye-hand coordination".

The Problem

A simple, portable, inexpensive mass screening device was designed and built by this researcher. The specific problem of this study was to determine whether this device was capable of detecting significant differences in manual-digital fine motor responses involved in a writing task.

Hypotheses

If the device designed for this study was to fulfill the role of a diagnostic tool in mass screening procedures to determine the level of manual-digital fine motor development in children entering school for the first time, its performance would have to be assessed by testing the following hypotheses:

1. That the characteristics of graphs produced when tasks were performed on the device would be significantly different when

the same task was repeated by the same person under conditions that were minimally different:

a) using the dominant hand, with eyes open, as compared with using the non-dominant hand, with eyes open;

b) using the dominant hand, with eyes closed, as compared with using the non-dominant hand, with eyes closed;

c) using the dominant hand, with eyes open, as compared with using the dominant hand, with eyes closed;

d) using the non-dominant hand, with eyes open, as compared with using the non-dominant hand, with eyes closed.

2. That the characteristics of graphs produced when tasks were performed on the device would be significantly different when the same task was performed by different people under conditions that were maximally similar:

   a) When all graphs produced under conditions of using the dominant hand, with eyes open, were compared in terms of the classificatory variables

      (1) sex, age group, educational level, typing group, years of typing experience, music group, number of instruments played, years of formal musical training, years of playing experience, typing-music group, and class of laterality, for the adult sample;

      (2) sex, age, number of years of nursery school attendance, number of half days per week of nursery school attendance, class of laterality, and Draw-a-Man score, for the nursery school sample.

b) When all graphs produced under conditions of using the non-dominant hand, with eyes open, were compared in terms of the classificatory variables

(1) sex, age group, educational level, typing group, years of typing experience, music group, number of instruments played, years of formal musical training, years of playing experience, typing-music group, and class of laterality, for the adult sample;

(2) sex, age, number of years of nursery school attendance, number of half days per week of nursery school attendance, class of laterality, and Draw-a-Man score, for the nursery school sample.

c) When all graphs produced under conditions of using the dominant hand, with eyes closed, were compared in terms of the classificatory variables

(1) sex, age group, educational level, typing group, years of typing experience, music group, number of instruments played, years of formal musical training, years of playing experience, typing-music group, and class of laterality, for the adult sample;

(2) sex, age, number of years of nursery school attendance, number of half days per week of nursery school attendance, class of laterality, and Draw-a-Man score, for the nursery school sample.

d) When all graphs produced under conditions of using the non-dominant hand, with eyes closed, were compared in terms

of the classificatory variables

(1) sex, age group, educational level, typing group, years of typing experience, music group, number of instruments played, years of formal musical training, years of playing experience, typing-music group, and class of laterality, for the adult sample;

(2) sex, age, number of years of nursery school attendance, number of half days per week of nursery school attendance, class of laterality, and Draw-a-Man score, for the nursery school sample.

Assumptions

The following assumptions were made in this study:

1. Intelligence of the adult sample was assumed to be average or better because of the academic level at which they were functioning or because of the professional competence they displayed in the execution of their duties.
2. The writing skill of the adult sample was assumed to have developed to an automatic level with a minimum of central cortical involvement in the execution of their tasks.
3. The laterality of the adult sample was assumed to have been firmly established, so that they were functioning habitually at their maximal level of manual-digital dexterity in the act of writing, whether they were right or left dominant.
4. The ability of the nursery school children to manipulate writing implements and execute certain figures was assumed

to have developed past the three-year-old level at which research has found they are generally able to use a pencil and paper to produce a vertical line and a circle.

5. Impediments of a neurological or motor nature were assumed to be absent from all members of the adult group.
6. It was assumed that the manual-digital superiority of the dominant hand reflected its higher level of fine motor development.

Definition of Terms

For the purposes of this study the following terms were defined:

Amplitude maxima: the six highest points of the graph of Task II, as determined by the use of a template with 1/10th inch rulings, and recorded as correct to the nearest 1/20th (.05) of an inch.

Amplitude range: the difference between the highest reading and the lowest reading of the amplitude maxima for any one graph of Task II.

Baseline: the distance, correct to 1/20th (.05) of an inch, between perpendiculars drawn through that point at which the graph indicated that the subject, in execution of a given task, first exerted pencil-point pressure upon the writing surface of the experimental device, and that task-completion point at which the subject ceased to exert pencil-point pressure upon that writing surface.

Graph: the line produced upon the moving paper by the pen that was, through a pantograph-like arrangement, attached to the writing surface of the experimental device, and which recorded the variations in pencil-point pressure upon it, during the execution of a given task.

Graph length: the actual length of the graph line as measured from the point marking the beginning of the baseline to the point marking the end of the baseline, correct to the nearest 1/20th (.05) of an inch.

Interval: the time between the completion of one section of a given task and the beginning of the succeeding section of that task; the time taken to reorganize response production processes.

Interval length: the time of the interval as translated into inches or fractions of inches by the graphing process and measured in a manner similar to the measurement of the baseline.

Interval identity: the identity of the measurements of interval length correct to the nearest 1/20th (.05) of an inch.

Pattern: that portion of a Task II graph that represented the execution of a repeated section of the total task, i.e. 1, 1, 1 or 0, 0, 0.

Pattern identity: the identity of the measurements of pattern length correct to the nearest 1/20th (.05) of an inch.

Pattern length: the time taken to execute a portion of Task II as translated into inches or fractions of inches by the graphing process and measured in a manner similar to the measurement of the baseline and the interval length.

Productivity ratio: the relationship between speed and graph length as computed by the formula

$$\frac{\text{graph length - speed}}{\text{speed}} .$$

Reflexive level: the level at which a learned motor response has become so automatic that only minimal clues are necessary to stimulate the higher cortical centres to select a desired response pattern and transmit the proper impulse to the lower centres involved in the execution of the fixed sequence of neuromuscular responses constituting that selected pattern.

Speed: the amount of time taken to execute any given task on the experimental device, and measured in units of inches and fractions of inches that constituted the baseline of the graph.

Design of the Study

The Pilot Study

The pilot study was conducted in two elementary schools of the Edmonton Public School System. All children from grades two to six, inclusive, were asked to write the standard sentence, "The quick brown

fox jumps over the lazy dog". A committee then selected the three best written samples from each grade and the three worst written samples, using the writing scales present in the schools as a basis for their decisions. The scores of the Detroit Beginning First-Grade Intelligence Test (Engel and Baker, 1935) which had been administered to all Grade One children were examined and a first-grade sample was selected by including the three children who scored highest and the three who scored lowest in subtest eight, the copying test. The total sample consisted of 105 children.

These children were asked to perform a variety of tracing and copying tasks, using the research device that had been designed and built for the study. (See Appendix I)

On the basis of the findings of the pilot study the experimental device was completely redesigned and rebuilt, in an attempt to eliminate as many as possible of the flaws that became apparent in its performance. The tasks to be executed were reduced in number and simplified in order to reduce the contamination of results by variables of work habits, scholastic ability and factors of experience and fatigue. The conditions under which tasks were carried out were also altered in order to minimize the influence of sensory acuity, perception and memory.

It was expected that the new design would enable the production of a graph which could be used to give a more reliable assessment of the level of manual-digital fine motor development.

The Major Study

On the basis of the evidence provided by the pilot study the major study proceeded as follows:

<u>The Sample</u>. - There were two groups.

1. Adult volunteers:

18	with graduate or post graduate training
31	with undergraduate-training
5	non-university trained subjects:
	1 business man 2 secretary-typists 1 electronics technician 1 sales clerk
54	Total

2. Nursery School Children attending a private nursery school, who had passed their fifth birthday. There were 62 children in this class. Two could not be tested because of absence due to illness, one was away on a trip with parents. The last girl tested was removed from the sample when it was discovered that by so doing, the number of boys and girls in the sample would be equal. The composition of this group then became:

29	boys
29	girls
58	Total

<u>The Testing Tasks</u>. - There were two tasks.

Task I - Adults wrote "fox jumps".

Task II - Adults and children wrote 10 10 10.

Each of the above tasks was carried out four times:

1. Using dominant hand, with eyes open

2. Using non-dominant hand, with eyes open
3. Using dominant hand, with eyes closed
4. Using non-dominant hand, with eyes closed.

Additional Data. - Pertinent information was obtained.

1. The handedness of each subject was established by a questionnaire in the case of the adults and by observation of the children as they used scissors, crayons to color pictures and the pencil during the test.
2. The dominant eye of each subject was determined through the use of a kaleidoscope.
3. A questionnaire was completed by adults regarding details of other activities and experiences that required manual or digital dexterity as well as other information considered pertinent. (See Appendix I)
4. Pertinent data about the children was obtained by consulting school files, school teachers and in two cases, by questioning parents.

Analysis of Data. - All graphs resulting from the execution of the testing tasks upon the research device were analyzed to derive quantified data.

1. Speed of task completion, expressed in units of inches, correct to the nearest 1/20th (.05) of an inch.
2. Graph length, expressed in units of inches, correct to the nearest 1/20th (.05) of an inch.
3. Productivity ratio, expressing the relationship between

speed and graph length.

In addition, the graphs produced during the writing of 10 10 10 (Task II) were analyzed to derive quantification of

4. Mean of the amplitude maxima, to assess the amount of pressure exerted during the task;
5. Range of the amplitude maxima, to assess the variation in pressure exerted during the task;
6. Pattern identity score, to assess the rhythm or periodicity of the performance;
7. Interval identity score, to assess the ability to reorientate and change direction during a rhythmic performance of a task.

These quantified data were entered on data processing cards together with the information of the classificatory variables that had been derived from the other data gathered at the time of testing. Fortran coded programmes for t tests and multiple linear regression were used with the IBM 7040 supplied by the Division of Educational Research Service, University of Alberta.

Limitations of the Study

Although the theoretical basis of this study extends widely into the field of learning theory, it was decided to limit it to a report of the statistical analysis of the responses of two widely disparate groups who carried out simple, basic tasks on a simple, inexpensive, portable device that was designed for this study, in order to evaluate this device as a tool for mass screening.

Other findings, based on the data processed in this study, are reported tentatively, not as firm conclusions that could be extended to the general population, but as indications that the device being tested was capable of extracting data from which valuable conclusions could be drawn about the particular sample used and the particular procedures followed at this time, in this study.

CHAPTER II

REVIEW OF RELATED RESEARCH

Four major areas of research were related to this study. It was necessary to differentiate between processes involved in psychomotor function in order that the area of fine motor control with which the current study is concerned might be identified. Its development through the interaction of learning and maturation could then be traced. Devices, past and present, used for the assessment of the developmental level of motor skills, were reviewed and evaluated in relation to the objectives of this study. Tasks executed upon these various devices were studied in the context of the sample this study proposed to use and the population its findings were designed to serve. Finally, the methods of scoring each of these sets of test were examined for the type of information they yielded and the value of such information from the viewpoint of the objectives of the present research.

Identifying the Fine Motor Process Under Study

Yates' chapter in the Handbook of Abnormal Psychology (Eysenck, 1961) begins

> The term PSYCHOMOTOR is defined by Warren (1934) as "pertaining to the motor effects of mental or cerebral processes." Within this general concept, he distinguishes two subtypes of function. Sensorimotor activity involves "responses which follow directly upon sensory stimulation"; whereas ideomotor activity involves "responses which follow upon thought processes, even though of a fleeting character." The term sensorimotor therefore, pertains to "neural activity, in which both the afferent and efferent segments of the neural arc are involved, or pertaining to the structure contained in such activity.

Although Yates characterizes this "method of conceptualizing certain kinds of behavior...(as)... obsolescent," he nevertheless feels that it is useful in the discussion of tests and methods used in differentiating between various psychomotor skills. He makes it clear, however, that in his opinion, both classes of psychomotor tests "are in no way concerned as such with motor ability".

> It is, in fact, implicitly assumed in many psychomotor studies that all subjects are equal in their ability as far as the motor act itself is concerned. ...Even where records of complex motor responses have been analysed (eg. Luria, 1932; Davis 1948), it has been assumed that these responses did not indicate impairment of the motor system itself (such as might follow injury to the motor cortex) but rather some kind of central disorganization which is reflected in the motor response.

The contradiction between this assumption of equality in the ability to perform a motor act and the body of research he cites in support of the choice and range of tests designed to measure the individual differences in responses to a variety of stimuli, Yates resolves by offering tasks that appear to be variously weighted in the degree of "speed and accuracy of central functions" required, in comparison with those "which can be said to involve individual differences in the skill required to make the response itself...". In Yates' opinion such procedure makes it

> ...easy to analyse finger or manual dexterity ... i.e. as a constant interchange of stimulus-response mechanisms.

He therefore organizes his test battery on three levels, according to the type of response required: A. Simple motor response mechanisms, B. Complex motor response mechanisms and C. Continuous motor response tasks.

In accordance with Yates' reasoning, it was felt that in order

to measure the motor skills in which the current study was interested, tasks designed to involve only level A., "Simple motor response mechanisms" would have to be presented. Brengelmann (Eysenck, 1961), adds support to this position when he states

> ...The reader should not overlook the fact that a test of greatest simplicity and short duration has achieved much better results than any of the complex drawing techniques discussed...

Since there is also a large body of research evidence that motor skills are specific (Seashore, 1928, 1930; Fleishman, 1954), these simple motor response mechanisms would have to be confined to those involved in tasks requiring the use of pencil and paper in a writing act.

Research has also documented the directional nature of human development: cephalocaudal, proximodistal and from mass to specific (Mussen, 1964), so it is known that development of fine motor control in hands and fingers occurs later than do many of the gross motor skills. Documentation of the progress from birth through childhood has formed the basis of many developmental scales, as well (e.g. Kuhlman, 1922; Shirley, 1931; Bayley, 1933; Cattell, 1947; Gesell, 1941, 1947), while studies to determine the relationship between training and maturation during motor skill mastery have revealed the importance of the latter factor, in the timing of skill trained activities (Hilgard, 1933; Dennis and Dennis, 1940; Gesell and Thompson, 1941). It therefore was necessary to take account of developmental factors when deciding upon the nature of the simple, motor, paper and pencil task by which the state of fine motor control in hands and fingers would be indicated, when a pre-school child was tested.

Research into the process by which a skill is acquired reveals

that it is a complex one, dependent upon other factors as well as those of directional development, maturation and response level requirements. Muscle-tendon-joint functions are the result of chemophysical processes involving neural networks, centred in the cortex and extending to all parts of the body. The efficiency with which this neural system produces responses in all muscles involved in the kinesthetic sense depends upon: (1) innervation ratio, (2) number of motor units involved, (3) summation which makes possible the sustained contraction of tetanus, (4) asynchronus innervation and discharge of motor units and (5) reciprocal innervation of opposed muscle groups.

Also involved in the production of movement is the structure of the nerve fibre (i.e. its diameter, length and perfection of construction) and the amount and quality of acetylcholine (ACH) present at synaptic junctures to facilitate transmission of nerve impulses. (Gardner, 1963; Wenger and Jones 1956; Encyclopaedia Britannica, 1961). When all chemophysical demands have been met and when all developmental requirements have been fulfilled, however, there is still the learning process to consider.

The learning of a skill is, like all learning, not only dependent upon the readiness of the organism for that activity, but also dependent upon the ability of the organism to integrate and organize components with accuracy and speed. Cerebral control becomes minimal once a skill has become perfected. There is evidence that cortical patterns that have been perfected through practice to the point where they have become automatic responses are relegated to a reflexive level; minimal clues, only, are required in order to stimulate the higher cortical centres into selecting

a desired response pattern and transmitting the proper impulse to the lower centres involved in its execution (Gardner, 1963).

The characteristics that identify a skilled performance have been listed variously, but basically similarly, by different observers of human behaviour. Psychologists are generally agreed that since movement is directed to the attainment of goals, purposefulness, directness and success are essential criteria, along with speed, accuracy, economy of movement and coordination. Coordination is defined by one writer (McDonald, 1960) as:

> ... the integration of specific responses required in the performance. The skilled performer has so integrated the responses in his performance that they appear to be one continuous movement ... characterized by grace and ease; there is no hesitancy, no abrupt shifting of movement, once the sequence has begun.

The relegation of a skill to the reflexive level is best understood from the definition offered by another psychologist (Cronbach, 1963).

> By skill we refer to a performance in which a complex sequence of actions is carried out in a more or less fixed way... The expert performs more smoothly and more automatically than others. Skilled performance is a series of actions, each regulated by clues; the expert senses relevant clues quickly, interprets them promptly and correctly, and runs off the sequence without pause.

Because the sequence is "carried out in a fixed way" and because "studies show that motor skills are well retained over long periods", once expertise has been established the speed of clue sensing and interpretation which results in the "sequence" being "run off ... without pause" becomes such that the speed of neural messages from the cerebral cortex is not great enough to immediately inhibit initiation of a sequence once the impulse for that initiation has been transmitted to the lower centres involved in its execution.

Physical educationists, speaking in terms of "efficient movement", tend to include terms from the vocabulary of physics in their discussion. Thus references are made to "force", "point through which force is applied", "energy", "tension" and so on. Broer (1966), for example, offers the following definition:

Efficient Movement

> The combining of coordinated movements to produce the force required by the particular purpose and to apply it through the most advantageous point, in the most advantageous direction, with the least expenditure of energy.

For a definition of coordination, however, this author is content to return to one offered by a pediatrician (Kraus, 1947).

Coordination

> The well timed and well balanced functioning together of several muscles in a single movement ...

She then elaborates it as

> ... the combining of simple movements without unnecessary tension and in proper sequence to make a smooth complex movement.

Obviously, then, the characteristics of a skilled motor performance or of efficient movement, that are considered criterial in the opinion of concerned professionals, are not of a type that can be evaluated from inspection of the performance during task execution nor from examination of the finished product after the task has been completed. Translation must occur through the intervention of a device, into a medium which facilitates quantification of differences in speed, accuracy, coordination,

economy of energy, fixedness of pattern and degree of tension present.

Tasks performed in the usual sensorimotor tests that involve pencil, paper and copying, depend on the use of the eyes to monitor the performance for the brain. It was felt by this researcher, therefore, that if the eyes were closed during execution of a written task, characteristics of the (translated) finished product would be the result of (1) the level of development that had been reached by the manual-digital fine muscle system and (2) the past experience of the individual that could be transferred to the performance of the required task. In other words, it could be a more accurate way of assessing motor readiness per se, than by including visual skills in the performance of a writing act.

Precedents for closing the eyes during experiments involving motor control are cited by Brengelmann (Eysenck, 1961). The most recent to be elaborated is Mira's work, using a technique designed in 1940 but reporting on its use in 1957.

> THE MIRA "MYOKINETIC" TEST (P.M.K.) .
> The demands of error control ... are to a large extent though not entirely, met by the "myokinetic" type of test, or P.M.K., as constructed by Mira (1940).
>
> Tests of this kind require the subject to start simple movement forms printed on the response paper, using full visual controls. After this, vision is blocked and the subject is required to continue the initiated movement which is now kinesthetically guided.

Brengelmann also makes reference to work that was done "long before Mira constructed his P.M.K. (Allport and Vernon, 1933)."

> ... In such tests, subjects were asked to draw three circles, waves, squares, etc., blindfolded. Reproductions were scored simply for size, amplitude, wave length, etc. The repeat reliability of

> this task was estimated to be 0.76 (Eisenberg, 1937). This is considerably higher than for Mira's P.M.K.. Although it may be argued that the test is far too simple to be of great use in the face of the great complexity of expressive movement, it has stood its ground for what it measures extremely well. H.J. Eysenck (1952a, 1952b) and S.B.G. Eysenck (1956) obtained highly consistent differences between normals, neurotics and psychotics... Further advantages are that this test is practically independent of intelligence and also very slightly related to age.

Since the reliability of this technique had been proven over the years, it was decided to include it in the present study.

Another dimension of fine motor control is often referred to as "rhythm". The dictionary definition of this term (Webster Collegiate, 1958), in the context of movement, consists of the following:

> Movement marked by regular recurrence of, or regular alteration in, features, elements, phenomena, etc.; hence periodicity.

Using this definition as a point of departure and the work of West (1922), Luria (1963), S.B. Eysenck (1955) and others cited by Yates and Brengelmann (Eysenck 1961) as a theoretical base, this researcher felt that a truer reading of fine motor development might be obtained in the present study from tasks performed when visual control was eliminated. However, to test whether the findings of other researchers, using other devices, could be validly extended to this study, it was decided to have the tasks performed first with eyes open and to repeat them with eyes closed. A comparison of the results would determine whether differences that other researchers had found, could be detected by the testing device of this study as well as limiting the skills involved in task execution so that the state of fine motor control could be more nearly estimated.

Another of the techniques used by Luria, the Eysencks and others, was that of repeating tasks with right and left hand. This, too,

was incorporated in the current study for two reasons. Firstly, the comparison of two such responses by the same person would eliminate the need for controlling for health, age, hidden factors of other relevant experience and background that might influence the scores of two different people. Secondly, this study, like the background of research on laterality and directionality (Brain, 1945; Swanson and Benton, 1955; Benton and Menee, 1957; Harris 1957; Spitzer, Rabkin and Kramer, 1959; Balow, 1963; Belmont and Birch, 1963, 1965; Coleman and Deutsch, 1964) is based on the a priori assumption that it is normal for a lateral preference to exist and for the preferred hand to be normally more adept than the non-preferred hand.

Thus a task, repeated four times under the varying conditions of (1) using dominant (preferred) hand, with eyes open, (2) non-dominant hand with eyes open, (3) dominant hand with eyes closed and (4) non-dominant hand with eyes closed would produce graphs that could be quantified to disclose whether the research device of this study was capable of discriminating between levels of manual or digital dexterity in the writing act, as measured by left and right hand differences. It might also be expected to provide insights into the relationship between visuo-motor acts and their more discrete motor elements, when direct visual control is eliminated.

Summary

In order to isolate, identify and assess the level of fine motor development processes used in a pencil and paper copying test of the type administered to children at school entry, the tasks performed would

be required to have the following characteristics:

1. Simplicity
2. Brevity
3. Suitability to the developmental level of the age group involved
4. Involve the use of pencil and paper
5. Contain repeatable elements or patterns
6. Eliminate maximally the effects of visual control
7. Control for the effects of experience, or practice.

Devices for Measuring Fine Motor Control

The most extensive and best documented recent research into handwriting has been the result of the work of the Committee on Research in Handwriting that was formed in 1949. It was chaired by Dr. Virgil Herrick, served continuously by Dr. Theodore Harris and Dr. Lawrence Rarick, and by other well known educationists for differeing periods of time. The published reports of the work of the Committee and the report of the international conference which it sponsored formed the point of departure for the research of this study into devices used to measure fine motor control of hands and fingers engaged in the writing act.

The Committee, supported by public and private grants, was able to use two types of instrument, both electronically designed. The first reported upon (Harris and Rarick, 1957), employed a platten upon which the writing act was performed, so that the pressure pattern of the writing act was translated into a graph which was quantified through the use of a formula to compute Force Variation Ratio.

Several of the assumptions, procedures and findings of this first report were incorporated into the design of the current researcher, although the requirements of the mass screening objective eliminated the use of mechanisms as expensive and massive as those employed by the Committee. The assumption that pressure variations could provide a measurable index of the state of fine motor control was also made by this researcher. The reading of the graph produced by the simple device was based on some of the reasoning that produced the formula used by Harris and Rarick (1957) and their finding that the pattern of the graph of a standard sentence (the quick brown fox jumps over the lazy dog) could be assessed by measuring the graph related to two specific words of that sentence (fox jumps), was also incorporated into the procedures that applied to the adult sample.

Research into the use of devices using the same mechanical principles as the one proposed for this study, however, began with Vernon's work of a much earlier date than that of the Committee (Vernon, 1934).

In his report on his "new instrument for recording handwriting pressure" Vernon describes his pneumatic stylus and the stylus methods of others as superior to the older platten-type methods, all of which he found to be variations of the Kraeplin Balance. Although he admits that in his opinion, the Kraeplin Balance type of device "still gives the clearest records", he nevertheless has reservations about "the results obtained with it" because they "suffer from the following drawbacks":

(a) Subjects dislike writing on a yielding surface and may

find it difficult to do so naturally.

(b) If the surface is supported on springs, it is not easy to eliminate the resonance effects which distort the tracings.

(c) Since the weight of the hands must not be allowed to influence the records, the hand must be supported above, or outside the edge of, the writing surface.

(d) The method only gives records of point pressure (i.e. of the point of the pen or pencil on the surface) not of grip pressure (i.e. of the thumb and first finger on the pen or pencil).

Harris and Rarick add to this list and expand, as well, upon Vernon's criticisms.

1. Writing surfaces supported by springs or balances tend to yield unduly to pressure exerted upon them, thus creating an unnatural writing situation for the subject.

2. Such writing surfaces frequently show unequal amounts of displacement when equal pressure is applied to various portions of the surface.

3. Satisfactory calibration of mechanical pressure recording instruments is difficult if not impossible, except for a restricted pressure range.

4. The use of levers, tambours and the like for the mechanical transmission of pressure introduces such problems as friction and leakage which contribute to the inaccuracy of the pressure records.

The failings of the Kraeplin Balance type of testing device led other researchers beside Vernon into using a stylus-like device. Herrick and Otto (1961) used an electronic implement of this type, which they called a "Grip Pressure Traducer Pen". But they discovered that grip pressure was generally so closely related to point pressure readings of the same act that the use of the pen was redundant. These

same researchers also rejected the pen because its size and construction "added to the artificiality of the handwriting situation".

It is interesting to note how the conclusions of Herrick and Otto differed from those of Wenger (1948), whose equipment also included both a writing surface to record point-pressure and a pen to record grip pressure, but whose design was a combined mechanical-electrical layout. Althouth Wenger found significant differences between grip and point pressure, he did not find his equipment really satisfactory. Redesign of both units was necessary:

> Actually the original table-switching mechanism was not as sensitive as was desired, and did not provide complete records for individuals who write with extremely light point-pressures. ... A four-point suspension of the writing-surface plate with a more simple switching mechanism supplemented by relays had obtained greater sensitivity in that portion of the apparatus.

He was not successful in his attempts to improve the pen. The problem of recording the "individuals who write with extremely light ... pressure" was also present in

> ... the pencil-switching mechanism. Furthermore, some individuals employ the index finger slightly or not at all in their grip of a writing instrument. From such individuals, a reliable record may be obtained by having them place the thumb instead of the index finger on the pencil lever, but for others this solution was not satisfactory. Attempts to design a simple pencil which will dispense with the level and permit a measurement of the summation of all aspects of grip pressure have been unsuccessful.

The increased sensitivity of electronic design that was present in the Herrick and Otto apparatus eliminated the need for using the pen, entirely.

Summary

A device proposed for use as a screening tool need not necessarily possess the ability to measure with the same degree of precision as one used in medical and related research. However, the failings and weaknesses of mechanical designs of the past should, if possible, be eliminated or at least minimized. The platten-type writing surface design seems to be superior to the pen type when electronic equipment is involved. Using a platten-type of mechanically constructed device might therefore be profitable in the sense that some relationship or continuity between electronic and mechanical devices might at some time be investigated.

Tasks Used in Measuring Fine Motor Control

Luria (1963) used tapping tasks whose graphs were recorded on a kymograph, to trace the restoration of motor function in his patients. West (1922) similarly recorded writing-like up and down strokes. Yates (Eysenck, 1961) lists cancellation tasks, simple reaction time tests of response to auditory or visual stimuli, and "Davis-type" tests, i.e. tests of controlled movement in adjusting simulated cockpit type instruments. Brengelmann (Eysenck, 1961) cites research that used mirror drawing and signature writing. Oetting (1959), used the writing of the letter "g" in his study of the relationship between stress and motor coordination. Cohn and Betheseda (1961) used a variety of writing tasks depending "on the age and training of the child".

> ... The most elementary test of graphic function consisted of copying a line, circle, and obtuse angle.

There was, however, a wide range of tasks through spontaneous production of letters of the alphabet, the subject's name, one syllable words (dictated), short sentences, lines of poetry or lines from the Lord's Prayer. These researchers also included drawings of the human figure, bird and dog houses, flowers and human houses. Responses were recorded on an EEG.

Wenger (1948) used single letters ("es and os"), a phrase ("a donkey loaded with salt"), and a complex sentence ("every army pilot goes through preflight primary basic and advanced training").

Harris and Rarick (1957), used the words "fox jumps" from the standard sentence "the quick brown fox jumps over the lazy dog", because the pattern of the two words was found to be characteristic of the pattern of the whole sentence.

Most of the above tasks were not suitable to the sample that was proposed for this study (i.e. pre-school children) nor did they meet some of the other requirements that had been decided upon as a result of an inquiry into the nature of motor skill processes. The words "fox jumps", however, could be used with the adult sample. They were brief, part of a standard sentence that was well known to the adult sample and their inscription might be expected to be an automatic response, without much central cortex involvement, because they had been practiced so often. They could also be classified as "writing" rather than drawing tasks, and might therefore, at some time, be able to provide a continuity between writing, as done by adults, and the drawing-like process which characterizes early writing efforts of children.

Since Gesell (1940) had found that a three year old could be

expected to draw a vertical line and a circular form, it was decided that a task involving these drawings should not prove too difficult for the children of the sample of the current study, who were all approaching their sixth birthday.

Both adult and nursery school groups would be able to perform a task of this nature and a comparison of the results between the two adult tasks ("fox jumps" and the vertical line and circle task), might perhaps give some indication of the relationship between them as a means of assessing the suitability of the one designed for the children.

Harris and Rarick (1957) also reported the high reliability of a "four line test" which they used. This consisted merely of drawing four horizontal lines. Vertical lines are more primitive in the skill development sequence of children than are horizontal lines (Gesell, 1940). The use of vertical lines would therefore involve a more practiced and therefore more automatic response than even horizontal lines might produce. The use of a task including vertical lines could, however, be considered to find some support in the findings of Harris and Rarick.

Summary

Only one of the tasks used by previous researchers was considered suitable for use in this study, and that task was only suitable for use with the adult portion of the sample.

A second task, based on the research of Gesell (1940) into the child's development of writing tools, would have to be devised. Both portions of the sample could perform such a task, and it might thus be possible to establish a continuity between "writing" (i.e. of words) and

"drawing" (i.e. of figures) as well as to relate this study to previous studies done in the field.

Quantification of Graph Data

The characteristics of a skilled motor performance, synthesized from the literature of medical, psychological and physical education specialists were listed in the summary of the first part of this chapter, dealing with fine motor skill processes. The determining criteria were considered to be speed, accuracy, coordination, economy of energy, fixedness of pattern and degree of tension present. These, then were the facets of the graph that would require quantification.

Harris and Rarick (1957) list the evaluation criteria of previous researchers. Yates and Brengelmann (Eysenck, 1961) both refer to the relationship between muscle tension and emotional state during motor acts. Luria (1963), as well as most of the other researchers mentioned, shows repeated concern with "rhythm", in discussing motor control. It is therefore increasingly apparent that the language describing traits of a skilled motor performance has to be translated into the terms of measurement used by previous researchers.

<u>Speed</u> is most easily measured in the manner described by Harris and Rarick (1957), since for the purpose of comparison, measuring the baseline of a graph is less complicated and would tend to be more accurate than the use of a stop watch, where electronic controls are not used. Measuring the baseline after the task has been completed also eliminates some of the stress of the testing situation upon subjects. They do not become aware that speed of response is being measured. It also spares

the researcher one detail, among so many that must be watched during an experiment.

Accuracy need not be taken into account in so far as the finished product of the writing act in this study is concerned. The quality of the writing per se of the words and numerals was not being studied. The tasks had been deliberately selected for their simplicity and for the fact that they required a level of competence far below the present status of the sample, so that the motor response to the task could be assumed to be on the automatic, almost reflexive level. If, therefore, both adults and children could be induced to reproduce the required material in recognizable form, allowing for the normal variations that are overlooked during the reading of handwriting, the total response of every subject could be considered accurate. This criterion was therefore deleted.

Coordination appeared to consist, in the opinion of the researchers who were reviewed, of smoothness and continuity of degree of force. Harris and Rarick (1957) measured these facets in several ways. They devised a force variation formula to compute the number of changes in direction of the graph line. They also used an average word force procedure that involved the use of an alternating planimeter which determined the area enclosed by the graph, and they divided this measurement by the length of the baseline. They further cite, in their report, the procedures of Roman (1936) and Pascal (1943), who computed the average pressure and range of pressure.

It became apparent, when graphs reproduced in their report were compared with those produced by the device that had been designed for this study, that it would not be possible to use any of their procedures. Their

graphs have sharp points that mark the changes in direction of the line, because of the speed and precision that an electronic design is able to provide. The graphs produced for this study were not of that calibre. Neither high nor low points were sharply enough delineated for easy or accurate counting.

The use of an alternating planimeter was investigated, but here too, the nature of the graphs made it highly unreliable. There was much variation in the results of repeated readings of the same graph by the same person. There was even greater variation between readings of the same graph, made by different people.

It was therefore decided that since the number of changes in direction would be reflected in the length of the graph line (i.e. the greater the number of changes, the longer the line would be), the length of the graph line could be used as the measure of the amount of work done during the time taken to complete the task.

<u>Economy of energy</u> could be quantified by a formula which was given the name of "Productivity Ratio", in this study, and which reflected the relationship between the length of the graph line as compared with the length of the baseline. It was felt that if enough graphs were processed in this manner, a norm could be established for mass screening purposes. Further study would be needed to interpret the cases of radical departures from this norm.

<u>Fixedness of pattern</u>, or "rhythm" of a writing act reflects the pattern of the sequential ennervation of the neural correlates of a motor pattern. Each completed sequence is followed by an interval in which the neural correlates of a sequence designed to facilitate the performance

graphs have shown more than once the changes in direction of the lines because of the speed [illegible] otherwise [illegible] to [illegible] easily [illegible] graphs. The graphs reported [illegible] lines [illegible] were out of [illegible] [illegible] and the errors were largely [illegible] [illegible] of [illegible] counting.

The use of an [illegible] instrument, [illegible] (p. 100), the method of the graph made it [illegible]. There was [illegible] variation in the results of repeated readings of the same graph by the same person. There was even greater variation between readings of the same graph made by different people.

It was therefore decided that since the number of changes in direction would be reflected in the length of the graph line, the greater the number of changes, the longer the line would be; the length of the graph line could be used as the measure of the amount of work done during the time taken to complete the test.

Economy of energy could be quantified by a measure which was given the name of "economy ratio". In this study, [illegible] the relationship between the length of the graph line as compared with the length of the [illegible]. It was felt that [illegible] in this respect, [illegible] for [illegible] purposes. Further study would be needed to [illegible] the [illegible] of [illegible] from this test.

Smoothness of movement or "shaking" of [illegible] the effects of the [illegible] of the [illegible] of a [illegible]. Such [illegible] the overall [illegible] of a [illegible] to [illegible] the performance

of the next task, are called into action. If the next task is a repetition of the first, fixedness of neuromuscular pattern should be reflected in the graph patterns: they should be almost identical. Similarly, the intervals between repeated tasks, since they recall into action a previously activated sequence, should also be almost identical in their graphed translations. It was therefore decided to measure rhythm of the performance by assessing interval patterns and task patterns on this basis.

The degree of tension present was found to be only partially quantifiable. Some researchers had found a relationship between degree of point pressure and emotional factors (Roman, 1936; Pascal, 1943; Ruesch and Finesinger, 1943: Steinwachs, 1950, 1952, 1953). Others, more recently, have also concluded that writing point pressure can be related to type of body build (Kretschmer, 1951). Brengelmann summarizes the research into this area (Eysenck, 1961) by reminding that not only can mentally abnormal states influence point pressure, but that many other factors can produce a similar effect. The effect of attitude, or set, the instructions given at the time of the test, the size of the writing, the type of writing implement used, and the degree to which overlearning has taken place also may influence the pressure exerted upon the writing surface.

On the basis of these findings it would be necessary to adopt procedures to minimize the amount of stress present in the testing situation, since Oetting (1959) had found that mild stress produced no deficit in performance during a short testing period. If this were done, average pressure and range of pressure, measures used by Pascal (1943),

could also be computed for this study for the purposes of norm development.

Summary

On the basis of the definition of a skilled motor performance and the relationship of previous research to the objectives, devices and needs of the present study, the following criteria were selected for quantification of graph data:

Speed measured in units related to the length of the baseline.

Productivity Ratio determined by the relationship between the amount of work done, as represented by the length of the graph line and the time taken to do that work, as represented by the length of the baseline.

Mean of the Amplitude Maxima that would indicate the average pressure exerted during the task execution.

Range of the Amplitude Maxima that would give an assessment of the degree of point-pressure variation between tasks.

Pattern Identity to evaluate the speed and accuracy of muscle response organization for a writing task.

Interval Identity to evaluate the speed and accuracy of reorientation of muscle response processes for a new or repeated task.

Summary of Chapter II

An attempt was made, in this chapter to ground in research, the design of the device being tested, the nature of the tasks to be performed upon that device and the method of quantifying the graph data that would result.

In order to do these things, however, the nature of the interaction between developmental and maturational factors of motor skill learning had also to be defined in terms that would make it possible to relate decisions of research design to these basic processes.

Having established the criteria which would have to be satisfied when such decisions are made, it is now possible to proceed with the discussion and description of the research design of this study.

CHAPTER III

EXPERIMENTAL DESIGN

The Sample Used in the Study

The major objective of the study was to examine the sensitivity of the device that was employed to record graphically the motor responses of a writing act and to determine whether the degree of sensitivity was adequate to detect significant differences in these responses. If adequate sensitivity could be proved, the device could, at a later date, be employed in mass screening procedures during the assessment of children entering school for the first time.

Adults.

Adult university students and professionals employed at the university in occupations calling for optimum mental and fine motor skills can be expected to be performing at an optimal level of development. It was therefore decided to invite volunteers from graduate and undergraduate classes and clerical and technical staffs.

There was no attempt to match or select subjects. Fifty four volunteers were accepted and subsequent analysis was made of the various characteristics of the volunteers. The objective in testing this group of adult volunteers was mainly to establish some basis of comparison between a stable group and the one by whom the device was actually intended to be used (i.e. pre-school children).

Children

The fifty-eight children used in the sample were all those attending a private nursery school in the neighborhood in which the researcher lives. Only children who had passed their fifth birthday were admitted into the sample. No other limitation was placed upon admission.

Nursery schools in this city are inspected only by the Department of Health. Curriculum, developmental activities, methods and materials are entirely within the province of the school staff. In this particular school no member of the staff had any teacher training, any training in early childhood education or any other qualification beside an interest in doing this particular type of work and an apparently unlimited degree of patience in the matter of putting on rubbers and fastening zippers. No attempt at evaluating the programme of the nursery school is made here and no implication of criticism is to be inferred as directed at the well intentioned group for whose cooperation this researcher is extremely grateful. An explanation is only undertaken in order that it may be understood that the classification of "school" is, under the circumstances merely a "courtesy title" and that this was simply a group of pre-school children of the desired age, conveniently available for testing and experimentation.

A questionnaire and a kaleidoscope test supplemented information provided by the motor test performance, in the case of adults. Pertinent questions involving experience in use of manual-digital fine muscles in other than acts of writing were asked, and other related data of the type usually secured in educational research, was also obtained.

Similar information about the children was noted. The number of years that a child attends nursery school and the number of half days per week attended could have an influence on the developmental level of his fine motor skills, as could the variables of sex, age and laterality. In addition the children were asked to draw a man and the drawings were scored according to the Harris modification of the Goodenough test (1963).

This information, classified in Tables 1 and 2, enabled examination

TABLE I

ANALYSIS OF ADULT SAMPLE

ON THE BASIS OF

THE CLASSIFICATORY VARIABLES

Variables	Sub-Class	Number
SEX	1. Male	19
	2. Female	35
AGE GROUP	1. Under 20	15
	2. 20 to 30	26
	3. 30 to 40	8
	4. Over 40	5
EDUCATIONAL LEVEL	1. Graduate or post graduate	18
	2. Undergraduate	31
	3. Technical-clerical (non-university)	5
TYPING GROUP	1. Non-typist	16
	2. Untrained typist	4
	3. Touch typist	34
YEARS OF TYPING EXPERIENCE	0 to 25; raw data entered	54
MUSIC GROUP	1. Non-musician	18
	2. Musician	36
NUMBER OF INSTRUMENTS PLAYED	0 to 8; raw data entered	54
YEARS OF FORMAL MUSICAL TRAINING	0 to 13; raw data entered	54
YEARS OF PLAYING	0 to 20; raw data entered	54
TYPING/MUSIC COMBINATION	1. Neither typist nor musician	8
	2. Typist only	10
	3. Music only	8
	4. Both typist and musician	28
LATERALITY CLASS	1. Homolateral	33
	2. Ipsolateral	21

TABLE 2

ANALYSIS OF NURSERY SCHOOL SAMPLE

ON THE BASIS OF

THE CLASSIFICATORY VARIABLES

Variables	Sub-Class	Number
SEX	1. Male	29
	2. Female	29
AGE	61 to 72 months; raw data entered	58
YEARS OF NURSERY SCHOOL ATTENDANCE	1. Attending first year	42
	2. Attending second year	16
HALF DAYS PER WEEK ATTENDED	3 or 5; raw data entered	58
LATERALITY CLASS	1. Homolateral	31
	2. Ipsolateral	27
DRAW-A-MAN SCORE	73 to 143; raw data entered	58

of the sample on the basis of two groups of classificatory variables for statistical analysis. It was thus hoped to gain further insight into the capabilities of the testing device to make fine discriminations between performances.

The Device Used in the Study

A completely new device was designed and built for the study. The objectives which guided the selection of materials and the construction of components were:

1. The researcher's original objectives for a mass screening device characterized by:
   (a) simplicity
   (b) use of readily available materials
   (c) use of inexpensive materials
2. Elimination of the flaws that had become apparent during the pilot study
3. Minimization of the influence of the characteristics which had been criticized by other researchers.

When completed the machine consisted of three components: a power unit, a paper travel unit and a writing table unit. Each was light enough to be carried easily with one hand, in suitcase style, and small enough so that they could all be placed on the back seat of a small car. As a matter of fact, for the testing of the nursery school sample, the three units were transported in one trip, using only a collapsible shopping cart of the type that is pulled along behing the shopper with one hand.

The Writing Surface Unit

The base of this unit was a piece of ½ inch plywood, 14 inches by 18 inches. Along one of the 18 inch sides was nailed a 1 inch board 6 inches wide with a 3 inch triangle cut from the centre of the top. This board was braced with 2½ inch angle brackets to insure its remaining square.

A second pair of 2½ inch brackets was mounted on the base, 4½ inches back from this board, so that their top holes were 12 inches apart. An ordinary tube-shaped curtain rod, purchased at a notions counter for 19¢ completed this segment of the unit and acted as a balance rod for the next. (See Fig. 1).

<u>The writing surface</u> consisted of two Z shaped brackets made of ½ inch aluminum. A piece of hardboard 2½ inches by 11 inches was riveted to one end of each bar and the bars were bent into a modified Z shape in such a manner that when hung over the balance bar of the above segment, the hardboard lay perfectly level and would return to level if depressed lightly for a moment and released. (See Fig. 2).

Four tiny eye screws and four little springs then completed the assembly. The springs used were cut from a long one, purchased for 10¢ in a hobby shop and it was of the type normally used as drive belts for toy steam engines. They are strong but flexible and easy to cut and mount. (See Fig. 3). A yard of nylon cord was threaded through a hole at the top of the hardboard and knotted close to the hole. The two strands were later knotted together again at the point necessary for efficient functioning of the pantograph in the paper travel unit.

A frame of 1 inch by 3 inch lumber was built around the front and sides of this base to within 2 inches of the back board. A 9 inch by 15 inch

Writing Surface Unit

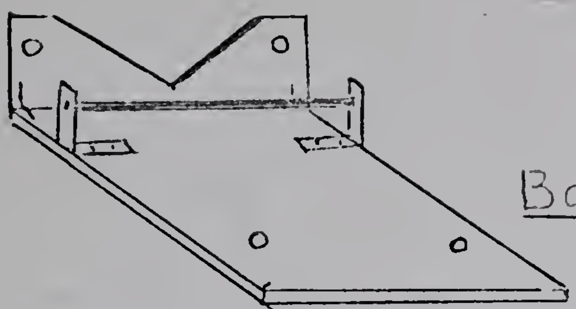


Fig. 1

Base - with brackets, balance rod and eye-screws in place.

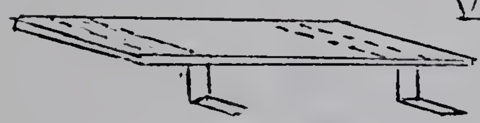


Fig. 2.

Writing Surface - hardboard riveted to aluminum brackets.

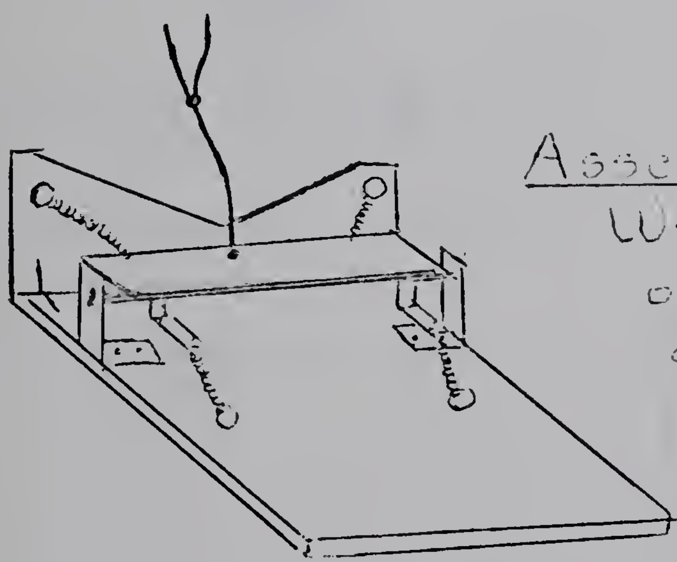


Fig. 3

Assembly Detail - Writing surface mounted on balance rod, control springs in place, nylon string attached.

Cut-away View - with steel arm-rest plate in place. Joining apparatus indicated

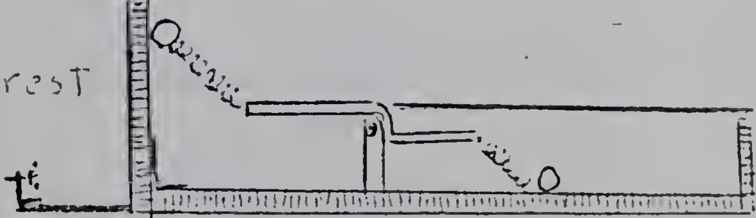


Fig. 4.

Fig. 5
Adapter Unit

POWER UNIT DETAIL

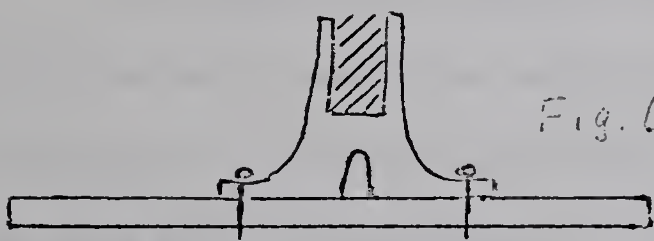


Fig. 6

Cut-away: showing detail of adapter unit mounted on turntable.

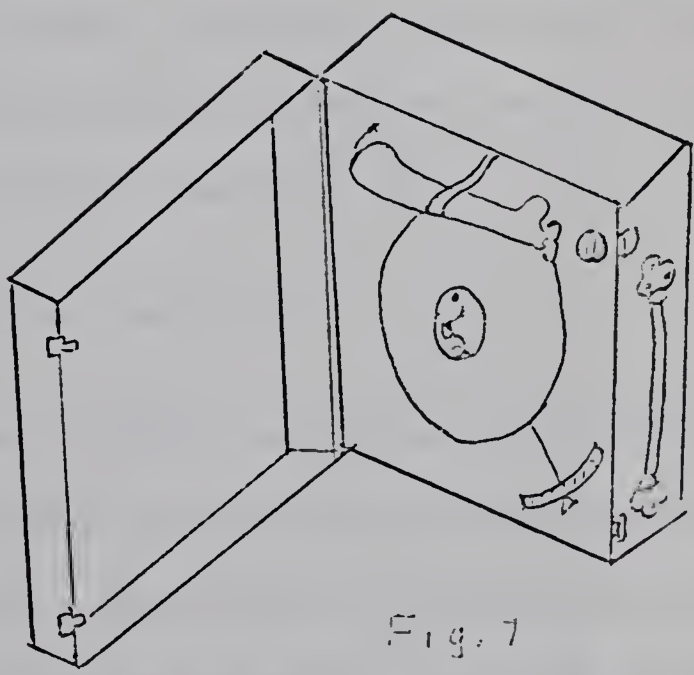


Fig. 7

Four-speed Record Player - in position for use as power unit

steel plate was mounted on this frame so that it almost touched the hard-board. This acted as an arm rest. (See Fig. 4). The joining apparatus was installed later when its dimensions could be determined.

The Power Unit

An inexpensive four speed record player was purchased for this section of the device. It was found that this procedure was more economical than purchasing a motor and mounting it and a rheostat in a suitable case. It was also found that the record player motor was quieter than any motor that was tested, and would therefore not distract or irritate testees.

An adapter was designed and made by a machinist. (See Fig. 5). It was threaded to match the shaft in the roller in the paper travel unit and mounted on the turntable with metal screws. (See Fig. 6). The record player was used with the turntable in a vertical position and the case lid used to steady and support the machine in place. (See Fig. 7).

The Paper Travel Unit

The first problem to be solved in this section was the conversion of vertical motion of the writing surface to the horizontal motion of the graphing pen without getting involved in complicated and expensive equipment. A pair of 59¢ lid support brackets proved to be adequate material for this purpose. (See Fig. 8).

The centre leg was cut in half and the head unit was modified by removing the two holes and drilling one hole instead in the flattened section. (See Fig. 9). A 2 inch corner bracket was used to re-unite the cut sections in a new direction and the stopper plug was removed from the end of the

PANTOGRAPH DETAIL :-

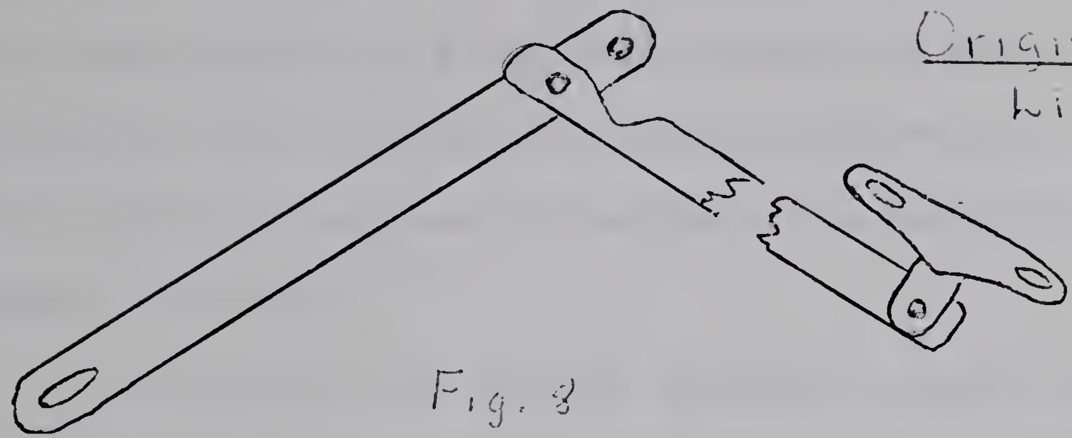


Fig. 8

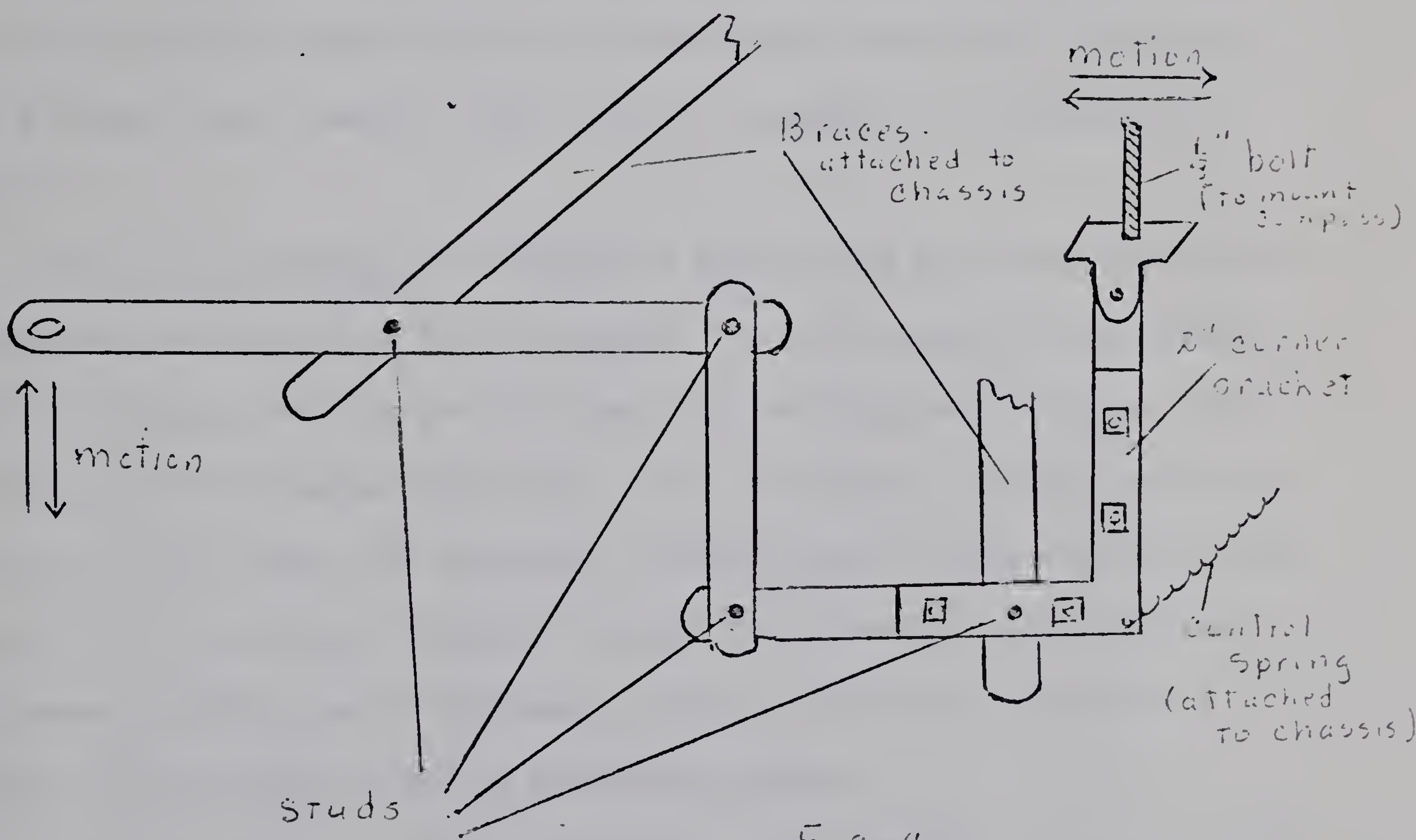


Fig 9

Modified Lid- bracket (Pantograph)

outside leg so that it could pivot freely. The outside leg of the second bracket was then attached with studs to the outside leg of the modified one, so that once again, there would be freely pivotting action. Two more studs were placed in the positions indicated in Fig. 9, to hold the unit in place by bars attached to the chassis upon which the unit was mounted. An 1/8 inch bolt inserted in the hole in the modified head completed this segment of the unit.

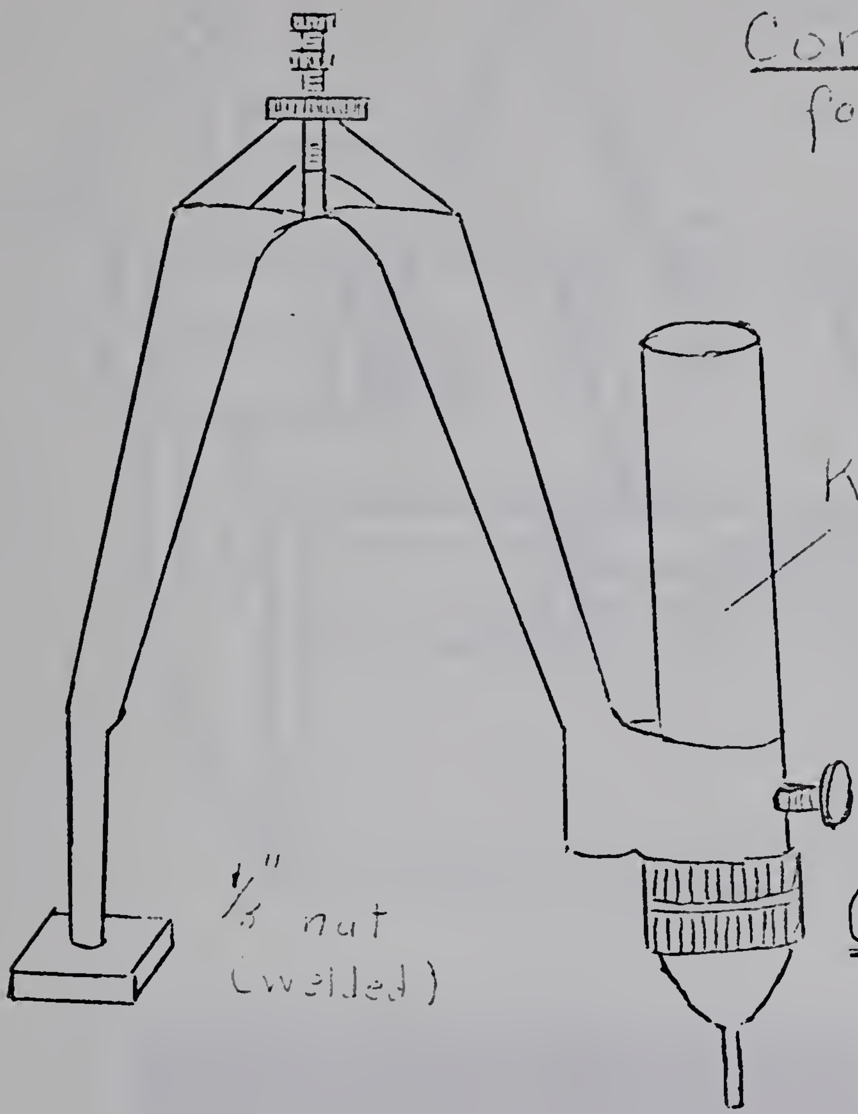
To hold the pens used for graphing, ordinary compasses were adapted. The needle section was withdrawn from the leg and 1/8 inch nuts to match the 1/8 inch bolts in the head of the motion conversion unit, were welded to the compass leg. (See Fig. 10). The total assembly is illustrated in Fig. 11.

The roller section which drew the paper along was constructed from a discarded adding machine roller assembly. It was stripped of all gears, bars and springs, and left on its frame with one large and one tiny roller still in place. The large roller was 1 inch in diameter and 4½ inches long and had a ¼ inch shaft that extended 2 inches beyond the edge of the roller. The end of this shaft was already threaded. The frame was then attached to a Hammond Utility Case with dimensions of 5 inches by 6 inches by 9 inches, with the shaft extending beyond the chassis.

Aluminun strips were bolted to the case to provide a channel along which the paper travelled. Other brackets, needed to support the pantograph-scriber unit were mounted on the case as needed. (See Fig. 12).

Assembly of the three units was simple and fast. The three units units were placed side by side on a table. The paper-travel unit was connected to the power unit by inserting the threaded shaft of the large roller into

Compass - Adapted for mounting on modified lid-bracket.



GENERAL DETAIL

Fig. 10

Schematic Representation of assembly to Translate vertical movement into horizontal movement.

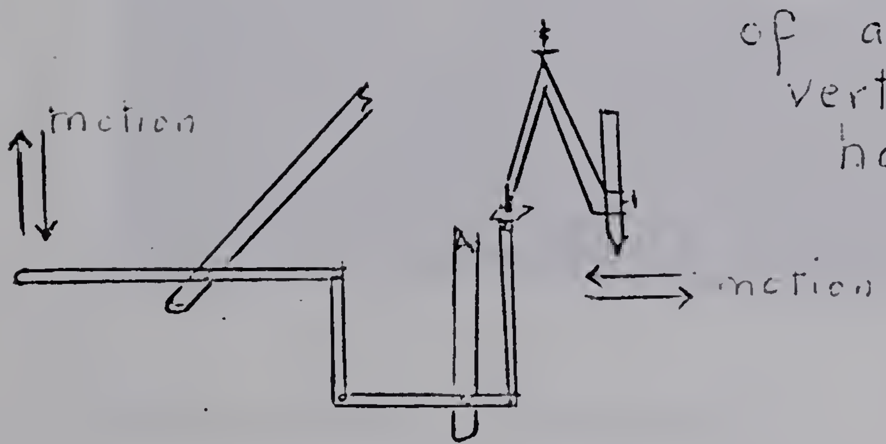


Fig. 11

PAPER TRAVEL UNIT

(Assembled)

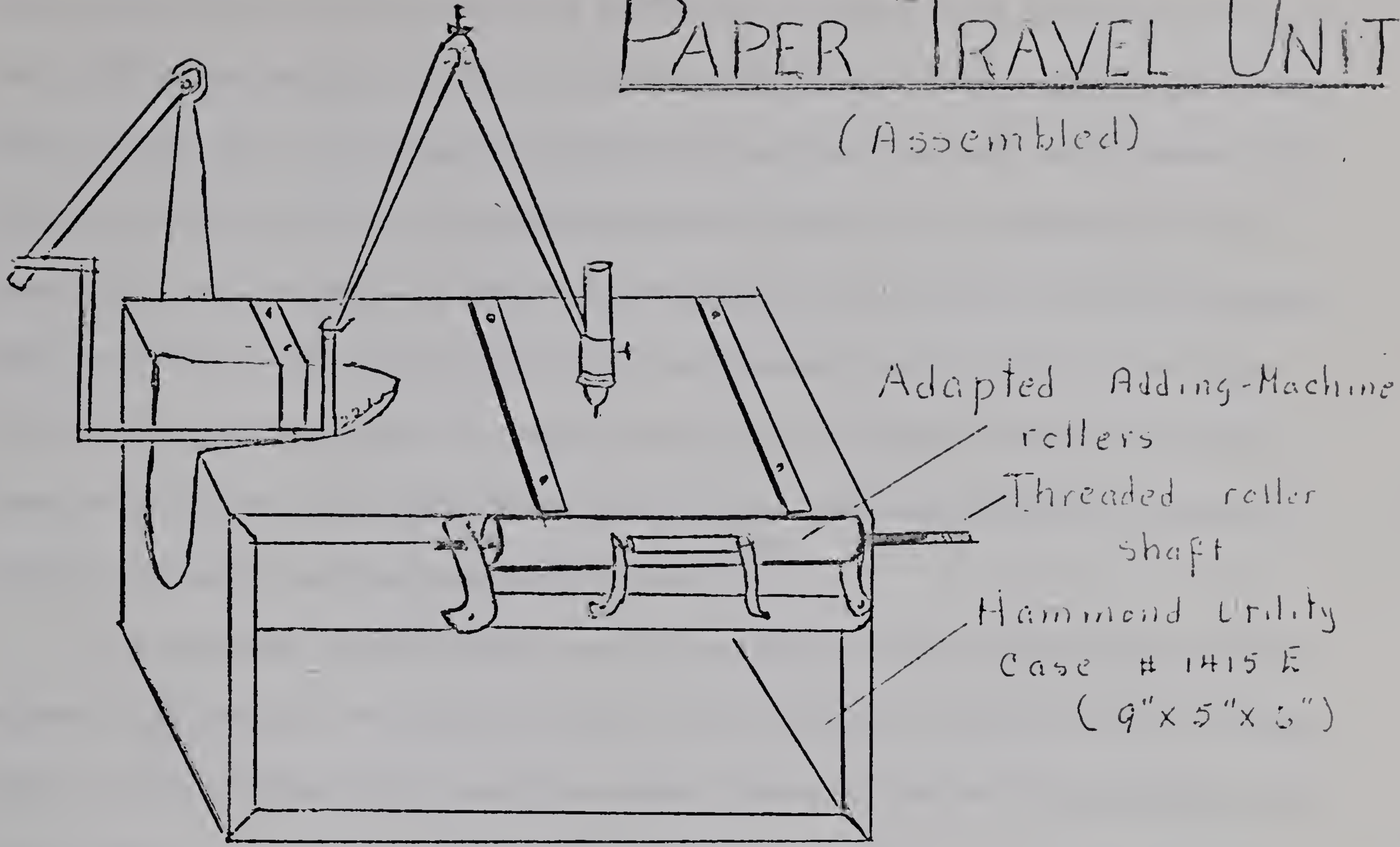
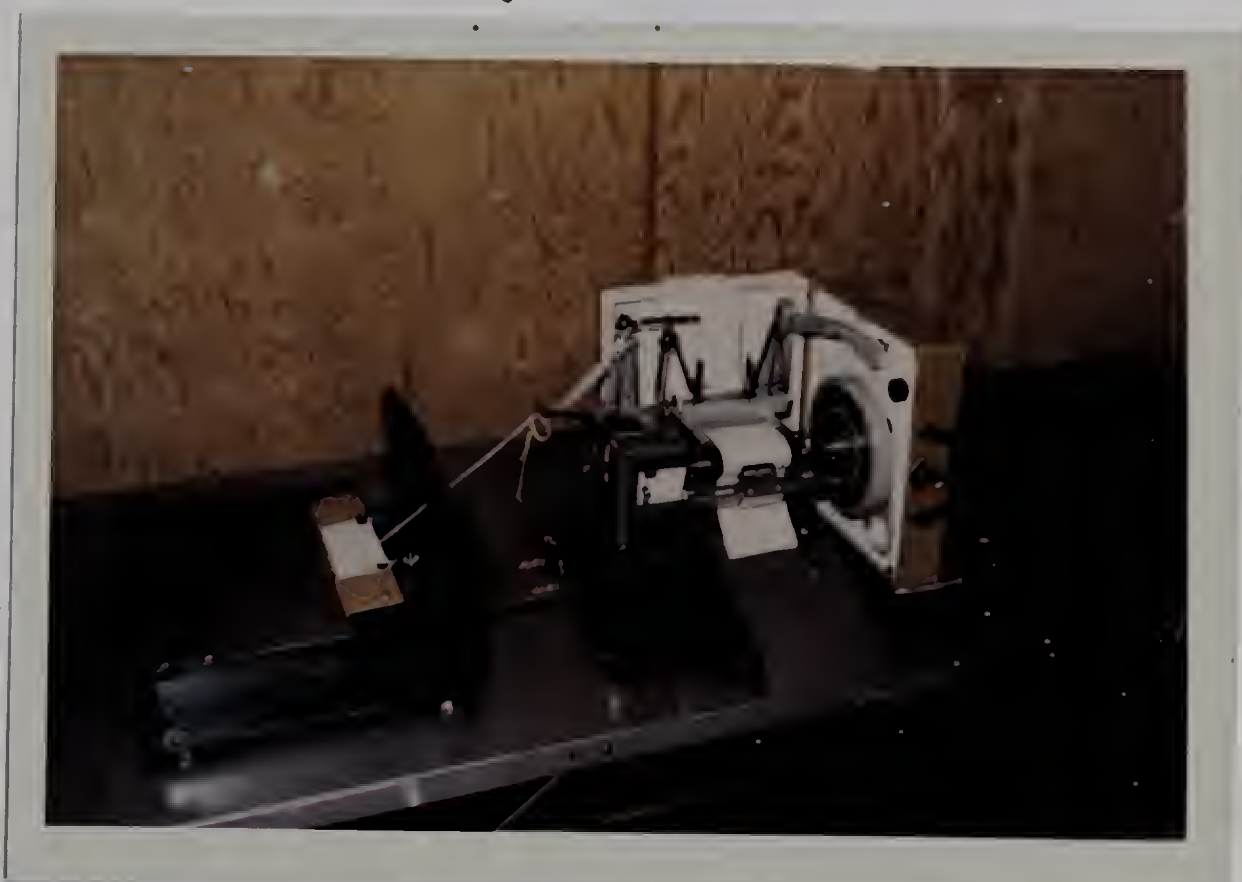


Fig. 12



THREE UNIT Assembly - Photograph

Fig. 13

the adapter unit on the turntable and rotating the roller manually until the two units were snugly attached to each other. The writing surface unit was then placed next to the paper-travel unit so that two sets of brackets that had been installed for this purpose, were in line. The brackets were then secured to each other with bolts and wing nuts, the nylon cord was inserted into the hole in the outer leg of the pantograph-scriber device and drawn up till the knot marking the proper length was reached. The cord was then tied and testing could proceed as soon as the pen was filled and inserted into the compass section designed to hold it.

The height of the table had to be adjusted for adults. The nursery school children had no problem since a low table was available that allowed them to write comfortably when the extra inches of the writing surface unit were added.

Discussion

As has already been noted during the description of the units in the preceding section, the problems of portability, paper travel, speed of paper travel, and influence of spring tension on the pressure of the pen (that prejudiced the results of the pilot study) were eliminated by the new design.

The specific criticisms of Vernon (1934) and Harris and Rarick (1957) were considered and dealt with as follows:
Both Vernon and Harris refer to the yielding surface. Vernon says that "subjects dislike writing on it", and Harris criticized the "unnatural writing situation".

It was felt that allowing the subjects to examine the machine and explaining to the adults what its purpose was, overcame any "surprise" and

eliminated the possibility of too much negative reaction to the yielding surface. It was also made clear to all subjects that this was not a test of handwriting, and that there would be no scoring of their handwritten sample: that it was only desired to see whether the graph produced by the machine indicated a difference between the performance of right hand and left hand under various conditions. The adults were generally admitted in groups and inspected each other's graphs as the machine produced them and often became very involved in discussing what they saw. Since they were all volunteers, usually from classes where research was discussed as a matter of course content, the yielding of the writing surface generally resulted in amusement.

The children, too, after being allowed to examine the machine and ask questions about the new "game" they were to play on it, were allowed to watch each other and examine the graphs that others produced, as well as their own. For this section of the sample all writing was "an unnatural situation".

Since the writing sample itself was of no consequence in this test, it might be considered that the need for pressure control on a yielding surface could be viewed as only another dimension of fine motor control of which account could be taken in the measurement of the graph produced.

The effect of this area of criticisms was therefore felt to have been minimized and considered as having only minor weight in the performance of the machine.

Vernon criticized a "surface supported on springs", and for the type of device he was discussing this researcher agrees with his argument, since the first and second design produced for this study supported his contention

that spring supported devices are unsatisfactory. The present device however did not have a spring supported surface. The only springs used were to keep the surface in line with the arm support plate and the springs that were installed pulled against each other rather than against the weight of the surface, and served only to steady or stabilize the surface as its own weight returned it to the starting point.

Harris' second criticism regarding the effects of spring resonance is a valid one, however, and care was taken to minimize the effects of this problem.

The area of the writing surface was measured out in three-quarter inch squares and the apparatus was set into action. Beginning at the upper left hand corner and proceeding across the top of the writing surface, three-quarter inch iron washers were carefully placed in turn on each square proceeding across the line. The graph depth-increase for each washer was noted. A similar procedure was followed along the next row of squares. These procedures were repeated over and over again, varying them in speed and in the number of washers placed over any square at one time.

In this way the area of greatest sensitivity and greatest uniformity was discovered to be 4½ inches wide and 1½ inches deep at the top centre of the writing surface. This area was marked off with ½ inch metal bar-clips. Two little magnets were purchased in a hobby shop: one in the shape of a white mouse, the other a lady-bug. When the writing tasks were executed they were done on strips of filing cards with holes punched in them on either side. The cards were laid over the most sensitive and reliable area of the writing surface so the holes fell on the metal bar-clips. The magnets were set over the holes. This not only held the cards in place firmly while the

writing was done but allowed the instructions given to the adults to be, "Please write on an imaginary line drawn between the two magnets". The children were quite entranced with the magnets and were allowed to handle and examine them. They were then asked to start "writing under Mr. Mouse's nose, so he can smell what you are doing". In this manner most of the writing was kept on the area marked out by top row of squares and the rest rarely went below the second row, even with eyes closed, so that the most accurate and sensitive area of the writing surface was used consistently.

Vernon's third criticism of the type of device used in this study concerned the weight of the hand, when writing. By keeping the writing surface narrow and providing a steel plate for the hand and arm to rest upon, the problem was eliminated for the adult sample. The children were asked specifically to try and "keep your hand off the bouncy part of the table" and since they were all inexperienced in the act of writing, they had no set method, manner or habitual writing position. They were all remarkably cooperative and very little problem was experienced with them in this or any other area of testing.

Vernon also objected because "only point pressure" was recorded by such devices. Harris and Otto, however, found subsequently to his research, that such a close relationship existed between the point pressure and grip pressure scores, that this criticism was ignored.

Harris' objection that "satisfactory calibration is difficult if not impossible" is well taken. However since this device is intended only as a screening implement it was felt that norms could be established for various features of the graph that would enable an evaluation to be made about the degree of "readiness" disclosed by the motor performance of the

child.

The mechanical problems of friction and leakage were minimized through the use of studs which were specially machined. Again, however, since the objective of this machine was only to eventually establish fairly wide norms that would indicate the need for more precise examination, and since the friction and leakage would be more or less standard for all subjects, no further attempt was made to deal with this problem.

The Tasks Used in the Study

On the basis of the conclusions reached as a result of the related research that was investigated, two tasks were used:

Task I

This task was performed by adults only. It consisted of writing the words "fox jumps" four times: once during each of the following conditions:

1. With dominant hand and eyes open (EOD)
2. With non-dominant hand and eyes open (EOND)
3. With dominant hand and eyes closed (ECD)
4. With non-dominant hand and eyes closed (ECND)

Task II

This task was performed by both adults and children. It consisted of writing the group of three numerals 10 10 10 under the same conditions used for the writing of Task I, namely EOD, EOND, ECD, ECND.

Testing Procedures

Adults

The majority of adult volunteers came from university classes who had been made aware of the project by their professors and were genuinely interested in taking part in research. When they presented themselves in the testing room they were allowed to examine the graphing device and all questions were answered. They were asked to fill out the questionnaire while they waited to take the test and were allowed to watch other subjects taking it. The yielding writing surface was drawn to their attention and they were asked to write as naturally as possible without resting anything but the pencil point on it.

Task I was given first. The subject was shown a card with the words "fox jumps" typed on it and asked to write those words when given the signal to start.

Task II was next completed, using a similar procedure. The card upon which the writing was done was immediately stapled to its graph and the next subtest, involving either a change of hand or eyes open, eyes closed condition, was introduced.

Whenever they wished to do so, subjects were allowed to examine their own graphs and compare them with those of others. There appeared to be no tension or nervousness that could influence the performance results and the fifty four volunteers all seemed to have performed in a relaxed, interested and natural manner.

<u>Children</u>

Several days were spent at the nursery school by this researcher, in the role of "teacher", and all activities were engaged in, exactly in the same manner as that of the other "teachers". When the children had accepted the presence of the researcher, the device was brought in. It was shown to

all the children and it was explained that it was going to be used by only those children who were "going to school next year", in order to see if they were "ready to write real words".

The instrument was left on a table and all the children were invited to examine it but cautioned that they could only "touch it gently and carefully". The clamor to be "first" to try it was ended by allowing one child, who because of leg braces could not join in the marching and dancing, to "try out the machine", while the rest watched to see "how well he can do on <u>this</u> job!" The stoical attitude of this child had been previously noted and his ready acceptance of his limitations and his disability without letting them defeat him in his attempt to extend the range of his activities had been admired. His attitude, as he performed the four subtests of Task II appeared to set the tone of the total response of the nursery school group. Each child, when called, came quietly to the table and did as he or she was asked. Each child was called in time to see the tasks performed by his predecessor, and if he wished, could linger after he had completed it and "help explain" to the child who followed him.

Only two children of the fifty-eight showed any symptoms of reluctance or shyness, and these were encouraged to watch and "help" the researcher explain to the others, for several days. It happened that one of the children attended the morning sessions, the other attended in the afternoon, so each child neither interfered with the "helper" role nor reinforced the fears of the other. Before the end of the week each had come quietly to the table and indicated a desire to carry out the task.

It was felt that this area of the procedures was very important because of the research that has linked tension and writing pressure (Harris

and Rarick, 1957; Brengelmann, in Eysenck, 1961).

Task II proved very easy for the nursery school children. It was not presented as the writing of numerals. Instead, the task was introduced by saying, "I know an easy way to make a bat and a ball for playing baseball. Here is the bat. See?" A vertical line was drawn. "Here is the ball". A circle was drawn.

The child was then given a piece of paper and asked, "Can you make bats and balls like that?". As the child drew the figures, he was cued: "A bat. Now a ball. Now a bat. Now a ball, etc..". This cuing was done deliberately because Luria (1963) found that providing of cues reduced the inhibiting effect of memory lapses when motor performances were being trained.

After the child had had the short practice session in which he was also helped if necessary, to hold the pencil correctly, he was seated in front of the "machine". He then completed Task II under the same conditions as had the adults except that the "cuing" continued. In order to keep the child from resting his other hand on the writing surface, he was asked to place it beside the machine during the eyes-open tasks, and to hold it over his eyes "so that you can't peek", during eyes closed tasks. As reported in a preceding section, there was little or no difficulty with this or any area of the testing procedures.

Treatment of Data

Scoring the Graphs

Task I

The graph of each section of Task I (limited to adults only) was subjected to a series of measurements in order that a quantified score for

each predictor might be derived.

Speed. The speed of task completion was measured in units of paper-travel-inches. The application of pencil point-pressure when the task was begun, immediately caused a departure from the baseline along which the graphing pen had been travelling. A perpendicular was drawn at this point. Another perpendicular was drawn through the point which marked the completion of the task, when pencil-point-pressure was being removed from the writing surface. The graphing pen here began its return to the baseline.

These two points were selected because they marked the extremities of the line resulting from the pressure in the interval during which the writer was responsible for the deviation from the baseline of the graphing pen.

The distance between the two perpendiculars was measured to the nearest 1/20 (.05) of an inch and became the speed score. This score would be negatively related to a good performance since a high score marked a slow performance.

Graph. In order to simplify the task of measuring the graph and reduce the margin of error, the graph of each task was inserted into an opaque projector which had been fixed in the position in which the image projected was a five time magnification of the original size. The image was then traced on white paper with yellow chalk and was measured by an inch counter (milometer). The length of the magnified line was then divided by five and rounded off to two decimal places, so that this score, too, was correct to the nearest 1/20th (.05) of an inch.

Productivity Ratio. The work done by the graphing pen during the time taken to complete the task was evaluated by the formula:

$$PR = \frac{\text{graph length in inches} \; - \; \text{speed score in inches}}{\text{speed score in inches}}$$

Task I received no further treatment at this time.

Task II

The graphs of Task II were measured for speed and graph length, in the manner described for Task I. Additional analysis was possible, however, since the same numeral had been written three times in succession in each sub-task and the repetitive features of the graphs produced during this task could be examined.

Amplitude Maxima Mean. A transparent plastic template ruled in lines 1/10th of an inch apart was placed over each graph and the two maximum amplitudes of each of the three sections of the subtask (10 10 10) were located to the nearest 1/20th (.05) of an inch. The mean of the six measurements was then calculated and rounded off at two decimal places.

It was discovered early in the scoring that some of the graphs of non-dominant hand performance were almost a straight line and that there was little or no measurable amplitude. Since, during the performance of the tasks this phenomena had been noted by the researcher to be the result of holding the pencil rigidly and employing large arm muscles rather than manual-digital fine muscles to "draw" the required numerals or words, an arbitrary procedure was adopted for scoring such graphs. Six "high points" were selected along the line and used in the calculation whether it could be ascertained that they belonged to patterns or not. The low scores that resulted from this procedure reflected the character of the graph and the poor performance of the hand. It was felt that the selected method complied with the objectives of eventually establishing a norm. Either end of a

normal curve should reflect abnormal graphing behavior.

Amplitude Maxima Range. The lowest of the six amplitude readings was subtracted from the highest reading to derive the range.

Although extremely large range can be interpreted as a poor performance, another facet of this measurement which was not taken into consideration during this study might prove of value in a clinical assessment of the whole child and his attitudes. It was noticed that many ranges varied widely in the maximum pressure of the initial sub-task and those of the succeeding sub-tasks. This variation represented the ability to adjust the second response on the basis of the results of the first and can be interpreted as an indication of adaptability. This feature was recognized during scoring only and there were therefore no notes that would tend to validate the interpretation, taken during actual task performance.

Pattern Identity Score. This score was derived by using the template to measure the baseline of each section of each subtask. Adults were given credit for the number of identical readings that were made. There was 1/10th inch tolerance allowed in the case of graphs produced by children because these graphs were considerably larger, indicating a slower performance and much greater pencil point pressure.

The possible scores on this section were 2 or 3 (out of three).

Interval Identity Score. This score was calculated by measuring the intervals between sections of each sub-task in the manner that has been described for the Pattern Identity Score (possible score 2 or 0).

Statistical Analysis

The graph scores of speed, graph length, means of the amplitude

maximi, range of the amplitude maximi, pattern identity and interval identity were entered on data processing cards along with the information of the classificatory variables that had been coded as illustrated in the analysis on pages 40 and 41 of this chapter.

Fortran coded programmes for the IBM 7040, supplied by the Division of Educational Research Service, University of Alberta, were used to facilitate the data analysis.

This analysis consisted of t tests for testing significance of means for dependent and independent samples and a multiple linear regression approach to one way analysis of variance was used to assess the effects of classificatory variables on the criteria.

It was decided to accept values as significant at the .05 level of confidence.

CHAPTER IV

ANALYSIS OF DATA AND INTERPRETATION

On the basis of the information derived from the statistical analysis of the data, two types of tables were prepared. The first type, Table 3 to Table 16, inclusive, shows the results of tests of significance for differences between means of the criteria which were used to quantify the evaluations of the graphs that resulted from the writing acts that were carried out on the research device. These criteria were speed, productivity, amplitude maxima means, amplitude maxima range, pattern identity score and interval identity score.

The second type of table, Table 18 to Table 31 inclusive, concerns the correleation coefficients that show the relationship between these criteria and the classificatory variables that applied to the sample.

Table 3 to Table 16, Inclusive

These tables fall into three distinct groups. Table 3 and Table 4 are related to Task I, in which adults wrote the words "fox jumps" four times: first using the dominant hand, with eyes open, then the non-dominant hand with eyes open, next the dominant hand, with eyes closed and finally the non-dominant hand with eyes closed. The non-repetitive nature of the letters that constituted the words used in the task made it possible to use only two criteria in analyzing the graph: speed and productivity.

Tables 5, 7, 9, 11, 13, and 15 are related to the analysis of the data secured from graphs enscribed when adults carried out Task II

on the research device. This task consisted of writing the numerals "10 10 10" under the same four conditions listed for Task I, namely, using the dominant hand with eyes open, the non-dominant hand with eyes open, the dominant hand with eyes closed and the non-dominant hand with eyes closed. The graphs that resulted from the performance of this task were analyzed, using six criteria: speed, productivity, amplitude maxima means, amplitude maxima range, pattern identity and interval identity.

Tables 6, 8, 10, 12, 14 and 16 relate to the performance of the nursery school children who were asked only to carry out Task II ("10 10 10"). The graphs produced by the research device, when this task was performed by the children, were analyzed similarly to those produced by the adult sample during this task.

Because of the nature of the evidence in these tables, each of the tables referring to adult scores will be discussed individually and then a comparison will be made between it and the corresponding table that deals with the tests of significance between means of the children's scores.

In this manner it is expected to be able to evaluate the performance of the device that was being tested in this study. Other significant information disclosed during these examinations will also be noted.

Tables 3 to 10, Inclusive

Table 3 shows that the means of speed in Task I, performed by adults, are significantly different in three of the four tests of

TABLE 3

TESTS OF SIGNIFICANCE FOR DIFFERENCES BETWEEN MEANS OF SPEED FOR ADULTS ON TASK I [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	3.35	15.31	0.00	**
EOND	6.19			
ECD	3.40	12.95	0.00	**
ECND	5.78			
EOD	3.35	0.48	0.63	N.S.
ECD	3.40			
EOND	6.19	2.36	0.02	*
ECND	5.78			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
 * = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

significance.

The difference between the performance of right and left hand is highly significant, whether eyes are open or closed. There is also a significant difference between the means of the speed of the non-dominant hand when the performance of this hand with eyes open and eyes closed is considered. Only the dominant hand shows no significant difference between the speed of eyes open and eyes closed performances.

The absence of any significant difference in this instance can however be accepted as logical if the fact is recognized that this sample had had a maximum amount of experience in writing. The simplicity of the two words (fox jumps) also can be considered as contributing to the ease with which the dominant hand was able to perform the required task, with eyes closed. The low level of difficulty enabled the response to be made on an automatic level, whether eyes were open or not.

Table 4 shows the results of tests of significance for differences between the means of productivity, when the adult sample wrote the words "fox jumps". The differences between the performances of the dominant and non-dominant hands are highly significant, whether the eyes are open or closed, but the productivity of each hand does not alter significantly whether the eyes are open or closed during the execution of the task.

As with the question of dominant hand speed, in Table 3, the lack of significance in these areas of Table 4 could be attributed to the maturity and experience of the adult sample. Patterns of response have been developed through practice, and the monitoring role of the eyes that is necessary during the skill-learning stage is no longer essential to the regulation of an automatic or habitual motor response.

TABLE 4

TESTS OF SIGNIFICANCE FOR
DIFFERENCES BETWEEN MEANS
OF PRODUCTIVITY FOR
ADULTS ON TASK I [a]

Task	Means	t Values	Probability	Sig.[b]
EOD [c]	0.33	9.69	0.00	**
EOND	0.13			
ECD	0.34	5.69	0.00	**
ECND	0.15			
EOD	0.33	0.46	0.65	N.S.
ECD	0.34			
EOND	0.13	1.41	0.16	N.S.
ECND	0.15			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
* = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

The role of practice is also evident from the highly significant differences between dominant and non-dominant hand performances.

Summary of Tables 3 and 4

Tables 3 and 4 contain evidence that the device designed and built for this study is capable of detecting significant differences between levels of fine motor control during a writing act. Logical analysis of the instances in which no significant differences were detected by the device suggests that the assessment of these cases is also valid, and that within the limits of precision demanded from a mass screening device, there were, in fact, no significant differences in performance in the areas being measured.

The tests of significance for differences between means on the criteria by which Task I graphs were quantified, therefore, uphold the first hypothesis. The characteristics of graphs produced when tasks were performed on the device were significantly different when the same task was repeated by the same person under conditions that were minimally different.

Table 5 shows the result of tests of significance between the means of speed for adults on Task II (the writing of the numerals 10 10 10). The pattern of significance is identical to that of Table 3 in which the speed of adults on Task I was under consideration. The areas of high significance, significance and no significance are exactly repeated. Repetition of results such as occurs here not only confirms the ability of the research device to detect significant differences, but establishes a continuity between tasks involving cursive writing and

TABLE 5

TESTS OF SIGNIFICANCE FOR DIFFERENCES BETWEEN MEANS OF SPEED FOR ADULTS ON TASK I[a]

Task	Means	t Values	Probability	Sig.[b]
EOD[c]	2.12	11.09	0.00	**
EOND	3.27			
ECD	2.09	9.17	0.00	**
ECND	3.01			
EOD	2.12	0.39	0.70	N.S.
ECD	2.09			
EOND	3.27	2.81	0.01	*
ECND	3.01			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
* = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

those involving inscription of numerals. The uniform pattern of the two tasks can, therefore, be accepted as one that is the result of the automatic fine motor responses of a maturity developed over the years by writing practice. There is then the implication that this is the pattern to which the continued development of children eventually is directed.

Table 6, that examines the result of tests of significance for differences between means of speed for children on Task II, indicates that nursery school children have an entirely different pattern of response to a writing act than have adults. There is no significant difference between the writing skill of the hands, in the area of speed. Whether the eyes are open or closed, the inexperience of the child in writing becomes evident. He has no neuromuscular patterns with the dominant hand that have been practiced until they have become automatic. His responses with either hand, whether eyes are open or closed, appear to be the result of transfer from other learnings, in which the responses of both hands are not significantly different in speed, when they require adaptation to an entirely new situation. Thus the first two tests of Table 6 produced results that were not significantly different.

When, however, the performance of each hand is examined, with and without the effect of visual monitoring, the result of the tests become highly significant. When eyes are closed, in both instances, the speed of performance increases in a highly significant manner.

From this evidence it would appear that when a child who has no writing experience is asked to "copy" figures, a true reading of his motor speed is not obtained. In addition, since the speed of performance

TABLE 6

TESTS OF SIGNIFICANCE FOR DIFFERENCES BETWEEN MEANS OF SPEED FOR CHILDREN ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	9.27	0.49	0.62	N.S.
EOND	9.11			
ECD	7.69	0.06	0.95	N.S.
ECND	7.67			
EOD	9.27	5.62	0.00	**
ECD	7.69			
EOND	9.11	4.32	0.00	**
ECND	7.67			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
* = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

is related to the availability of motor patterns for the task, it would appear that asking a child to "copy" actually interferes with the disclosure of his true motor potential for the skill that is being investigated. The monitoring function of the eyes inhibits this disclosure.

The efficiency of the research device, however, is still supported by the evidence in Tables 5 and 6, which in both cases, upholds the first hypothesis.

Table 7, depicting the result of tests of significance for differences between means of productivity of adults on Task II (the writing of numerals 10 10 10), produces an identical pattern to that of Table 4, in which the productivity of adult graphs resulting from the cursive writing of words was examined. Once more the continuity between tasks is evidenced in the performance of adults.

Table 8, shows the results of the tests for the same factors as those considered in Table 7, when the task was executed by the nursery school children. This table contains highly significant differences between the means of productivity in all areas.

Performances of dominant hand are significantly different from those of the non-dominant hand, whether eyes are open or closed. An examination of the means shows the dominant hand to be at least twice as productive as the non-dominant. This does not hold true in the case of adults (see Table 7), although both children and adults produced highly significant differences in this area.

When the performance of each hand is considered, the children's graphs once more produce evidence of the inhibitory role of visual

TABLE 7

TESTS OF SIGNIFICANCE FOR

DIFFERENCES BETWEEN MEANS

OF PRODUCTIVITY FOR

ADULTS ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	0.77	4.85	0.00	**
EOND	0.46			
ECD	0.87	4.65	0.00	**
ECND	0.49			
EOD	0.77	1.32	0.19	N.S.
ECD	0.87			
EOND	0.46	0.71	0.48	N.S.
ECND	0.49			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
* = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 8

TESTS OF SIGNIFICANCE FOR DIFFERENCES BETWEEN MEANS OF PRODUCTIVITY FOR CHILDREN ON TASK II[a]

Task	Means	t Values	Probability	Sig.[b]
EOD[c]	0.36	6.93	0.00	**
EOND	0.18			
ECD	0.63	8.13	0.00	**
ECND	0.31			
EOD	0.36	8.45	0.00	**
ECD	0.63			
EOND	0.18	5.43	0.00	**
ECND	0.31			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
* = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

monitoring during the performance of a task for which neural patterns have not yet been perfected. Whereas, during the execution of a simple task calling upon writing skills that are very primitive in the developmental sequence (i.e. the making of a vertical stroke and a circle), adults show no significant difference between an eyes open and an eyes closed performance, no matter what hand is used, children show great increases in productivity when the eyes are closed. The results of tests of significance between these means are highly significant.

Summary of Tables 5, 6, 7 and 8

Tables 5, 6, 7 and 8 are concerned with the criteria of speed and productivity of both adults and children on Task II. The performance of adults in these areas disclosed a continuity between Task I and Task II. The patterns of performance of the children differed from the patterns of the adults. Analysis of the difference in the light of the children's inexperience with the writing act suggests that with maturity the inhibitory role of the visual monitoring processes is almost entirely absent from simple grapho-motor responses.

There is also evidence that with maturity the speed and productivity of the non-dominant hand comes closer to that of the dominant hand, than it does with immature children. Whether the reduction of difference is due to transfer of training from similar activities or from contralateral motor irradiation of the non-dominant cerebral hemisphere, as suggested by Cernacek (1961), it would appear that growth toward maturity is signified by the reduction of differences between means of the performances of the non-dominant and the dominant hand, in speed and productivity of each

hand with eyes open compared with eyes closed.

Tables 5, 6, 7 and 8 also support the first hypothesis that the research device will detect significant differences. The characteristics of graphs produced when tasks were repeated by the same person, under minimally different conditions, were significantly different.

The second hypothesis is also partially upheld by these tables. The tests of significance between means of the criteria of speed and productivity produced patterns for adults and patterns for children. These patterns were different. Thus, it can be assumed that when the same task is repeated by different people under different conditions, the research device is capable of detecting differences in the performances. Whether these differences are great enough to be significant will have to be determined when the correlation coefficients showing the relationship between the tasks and the classificatory variables are examined.

Table 9, showing the differences between means of the amplitude maxima means on Task II provides supportive evidence for the conclusion that the inhibitory nature of visual monitoring during an "eye-hand coordination" task, tends to mask the actual state of motor development, even when adults are concerned.

Whereas the eyes-open-eyes-closed comparison of the performance of each individual hand shows no significant difference in each case, the result of between-hand comparisons, which are only significant at the .02 level of confidence, when eyes are open, becomes highly significant (at the .00 level of confidence), when the eyes are closed. It suggests that there is less difference between the hands in an open eyed performance because, during his lifetime, an adult will have had many occasions to

TABLE 9

TESTS OF SIGNIFICANCE FOR DIFFERENCES BETWEEN MEANS OF AMPLITUDE MAXIMA MEANS FOR ADULTS ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	0.31	2.50	0.02	*
EOND	0.25			
ECD	0.31	3.78	0.00	**
ECND	0.23			
EOD	0.31	0.07	0.94	N.S.
ECD	0.31			
EOND	0.25	1.13	0.26	N.S.
ECND	0.23			

[a] Degrees of Freedom = 1,53

[b] ** = $p < .01$ = highly significant
 * = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

repeat with his non-dominant hand, and eyes open, a type of task which he had performed with his dominant hand. One of the obvious functions of visual control of a motor act is in the interests of the need to coordinate the sub-processes which constitute any total neuro-motor process. Such coordination would tend to have a levelling effect on the components, and since the upgrading of the inferior components depends upon practice, the only alternative is to downgrade the superior ones.

When visual monitoring is eliminated the actual level at which each component is capable of functioning seems more likely to be exposed for assessment.

Table 9, therefore provides additional evidence that fine motor development and control, as it applies to a writing act, cannot be assessed from an eye-hand coordination task. It also provides further evidence that the research device is capable of detecting significant differences in performance when the same person carries out the same task under conditions that are minimally different. The first hypothesis is, therefore, again supported.

Table 10, examines the same area of performance for children as does Table 9 for adults. The pattern of significant differences, though it is almost entirely different from that of Table 9, nevertheless gives substantial support to the conclusions drawn from that table. The inexperience of the nursery school children in motor tasks involving paper and pencil is clearly evident in Table 10. Adults showed no significant difference between eyes open and eyes closed performances with the same hand, because the task was one in which, through practice, it appeared they were able to employ automatic responses. Lacking that practice, and that repertoire

TABLE 10

TESTS OF SIGNIFICANCE FOR

DIFFERENCES BETWEEN MEANS

OF AMPLITUDE MAXIMA MEANS FOR

CHILDREN ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	0.47			
		7.07	0.00	**
EOND	0.25			
ECD	0.59			
		10.22	0.00	**
ECND	0.31			
EOD	0.47			
		4.58	0.00	**
ECD	0.59			
EOND	0.25			
		3.14	0.00	**
ECND	0.31			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
* = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

of automatic responses, the performance of children on this area of the second task, showed highly significant differences.

Children have also not had the opportunity that time has offered to adults, and so they have had less practice in repeating, with eyes open, a manual-digital fine motor task with the non-dominant hand, that had been performed with the dominant one. They are equally naive with either hand in the matter of adapting to minimal changes in the conditions of performance. The device that was being researched therefore detected highly significant differences between the means of the amplitude maxima means under all conditions of the nursery school children's performance. The first hypothesis again finds support.

The second hypothesis concerning between-person differences in performance would also appear to find some support from the differences in pattern between Table 9, concerning adults, and Table 10, concerning nursery school children in precisely the same area. Whether the patterns of the two tables are significantly different was not established by this study, but later tables dealing with correlation coefficients showing the relationship between the criteria and the classificatory variable might lend support to the present tentative acceptance of a significant difference, based upon visual inspection of the tables.

Table 11, contains an analysis of the differences between means of the amplitude maxima range for the adults on Task II. An interesting observation made during the actual performance and during the scoring of the graphs, was found to be highly significant when the results were subjected to statistical analysis. Generally adults exerted the greatest amount of pencil-point pressure during the execution of the first part

TABLE 11

TESTS OF SIGNIFICANCE FOR
DIFFERENCES BETWEEN MEANS
OF AMPLITUDE MAXIMA RANGE FOR
ADULTS ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	0.12	3.27	0.00	**
EOND	0.17			
ECD	0.12	2.39	0.02	*
ECND	0.16			
EOD	0.12	0.07	0.94	N.S.
ECD	0.12			
EOND	0.17	0.88	0.38	N.S.
ECND	0.16			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
 * = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

of Task II, and as they continued the task they reduced the amount of pressure, so that the final section of the graph usually had the least amplitude. It was noted that the greatest amount of correction, or adaptation, of this nature took place when the dominant hand was used. This insight into the more flexible ability afforded to the dominant hand was borned out by the statistical analysis which showed the difference between non-dominant and dominant hand to be significant whether the eyes were open or closed. Although the between-hand performances with eyes open is highly significant whereas with eyes closed it is merely significant at the .02 level of confidence, the exact nature of the influence of visual control in this instance, is difficult to explain in view of the lack of significant differences in the repeated performances of the same hand with eyes open and then with eyes closed. In this latter area, the differences are not significant. Whether this lack of significance can be attributed to an emotional reaction to the device that prevented learning from the first experience (with eyes open) or whether it discloses a limitation of the research device, cannot be determined from this study. Certainly, one might expect adults to learn from repeated performances of a simple task. It could, therefore, very well be an indication that the sensitivity of the device was not equal to the need for fine measurement of the amount of learning that took place during the short time required by adults to repeat the writing of three sets of numerals (10 10 10). The degree to which this lack of sensitivity to the performance of adults (if it is indeed responsible for the results mentioned above), constitutes a real shortcoming in the ability of the device to serve in mass screening of children, will have to be assessed by examination of tables relating to the performance

of children.

Table 12 deals with the differences between the means of the amplitude maxima range when the nursery school children executed Task II. It is the counterpart of Table 11 and once again illustrates the essential differences between the performances of the two portions of the sample. The lateral dominance of the children is seen to be less firmly established than that of adults. As a result there is less difference in the adaptibility of the dominant hand compared with the adaptibility of the non-dominant, as determined by the ability to reduce the amplitude of the graph by reducing pencil-point pressure. The difference between means of the range of the hands, with eyes open, for adults, was significant at the .00 level of confidence. For children it was at the .03 level. The between-hand differences with eyes closed, in the matter of range, was significant at the .02 level of confidence for adults. For children the difference was not significant: the dominant hand had no experience upon which to call, in order to give its performance superiority. For this task, it might be concluded, the hands were equally inept in the matter of adjusting, adapting or learning from this totally new experience.

The role of vision in the learning of a new skill is once more emphasized when the eyes-open-eyes-closed performance of each hand is examined separately. The dominant hand, though naive in the particular task that is being required upon the research device, nevertheless has developed some response patterns that have become habitual or automatic. This is evidenced by the fact that the difference between its eyes-open and eyes-closed performance is only significant at the .05 level of confidence. The non-dominant hand has as yet no such repertoire in its background. When

TABLE 12

TESTS OF SIGNIFICANCE FOR

DIFFERENCES BETWEEN MEANS

OF AMPLITUDE MAXIMA RANGE FOR

CHILDREN ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	0.37			
		2.26	0.03	*
EOND	0.31			
ECD	0.44			
		0.09	0.93	N.S.
ECND	0.44			
EOD	0.37			
		2.00	0.05	*
ECD	0.44			
EOND	0.31			
		3.71	0.00	**
ECND	0.44			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
* = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

the eyes are closed the deterioration in control of the amount of change in pencil-point pressure becomes significant at the .00 level of confidence (i.e. highly significant).

These results would tend to minimize the degree of concern that need be shown regarding the possible failure of the research device to measure the "on the job" learning of the adult sample, that was expressed during the discussion of Table 11. The device was designed with pre-school children in mind, and seems to be performing adequately when such children are involved.

Table 13, is an analysis of the adults' pattern identity score results. When the means of these scores are tested for significance, the between-hand performances differ in a highly significant manner whether eyes are open or closed, while the individual hand performances do not differ significantly. Visual inspection of the means discloses a marked superiority of the dominant hand. Yet the performance of the non-dominant hand is consistent. Neither hand shows any significant difference between eyes-open and eyes-closed performance. Translated into neural processes theory, these results could be taken as evidence that the neural patterns available for this writing task with either hand, have reached an automatic level in which the role of the eyes as monitors of the task is no longer necessary. Because the dominant hand has had more practice over the years, it is more capable of recalling into action identical neural processes and of repeating them in an identical manner, than is the non-dominant hand. Once again the significance of contralateral motor irradiation (Cernacek, 1961) might provide an interesting area of study in this connection.

Table 14, supports the conclusions made as a result of the findings of Table 13. None of the tests for differences between means of pattern

TABLE 13

TESTS OF SIGNIFICANCE FOR

DIFFERENCES BETWEEN MEANS

OF IDENTITY OF PATTERN SCORE FOR

ADULTS ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	1.26	3.20	0.00	**
EOND	0.63			
ECD	1.06	3.57	0.00	**
ECND	0.50			
EOD	1.26	1.09	0.28	N.S.
ECD	1.06			
EOND	0.63	0.84	0.40	N.S.
ECND	0.50			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
  * = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 14

TESTS OF SIGNIFICANCE FOR
DIFFERENCES BETWEEN MEANS
OF IDENTITY OF PATTERN SCORES FOR
CHILDREN ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	0.66	0.94	0.35	N.S.
EOND	0.79			
ECD	0.90	0.69	0.50	N.S.
ECND	0.78			
EOD	0.66	1.34	0.18	N.S.
ECD	0.90			
EOND	0.79	0.10	0.92	N.S.
ECND	0.78			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
 * = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

identity scores for children on Task II produced results that were statistically significant. Translated into neural theory, this discloses that with neither hand have the children yet developed neuro-motor patterns for the type of task demanded in this study. They can therefore not recall such patterns into action for task repetition. Both statistical analysis of the scores and logical examination of the situation lead to the conclusion that identical repetition (or rhythmic repetition) is only possible after a skill, through practice, has become established on an automatic level. Since nursery school children have not had the necessary practice, the research device was quite accurate in detecting no significant difference in the performances between hands, whether eyes were open or closed as well as in the performance of each hand, whether eyes were open or closed. Under all conditions, both hands were equally inept.

Tables 13 and 14 can, therefore also be interpreted as supporting fully the first hypothesis regarding the efficiency of the research device. They also support the second hypothesis in part. Differences are detected between the adult sample and the nursery school sample. From a normative point of view, it appears to also be capable of indicating the trend that is followed by the process of development toward maturation.

Table 15, deals with the tests of significance for differences between means of identity of interval scores for adults on Task II. None of the results are statistically significant.

It is felt by this researcher, after having experienced the difficulty of measuring the intervals on the graphs, that the unit of measurement (i.e. correct to .05 of an inch) was not adequate to give precision, when the performance of adults was involved. The intervals between tasks were,

TABLE 15

TESTS OF SIGNIFICANCE FOR
DIFFERENCES BETWEEN MEANS
OF IDENTITY OF INTERVAL SCORE FOR
ADULTS ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	0.78	0.72	0.47	N.S.
EOND	0.67			
ECD	0.81	1.09	0.28	N.S.
ECND	0.63			
EOD	0.78	0.23	0.82	N.S.
ECD	0.81			
EOND	0.67	0.24	0.81	N.S.
ECND	0.63			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
 * = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

in themselves, generally comparatively small. Since they reflected the speed with which neural reorganization was effected in order to orientate the response system toward repetition of the task-section just completed, it was only to be expected that the reaction of adults would be too rapid for gross units of measurement. On the other hand, for mass screening purposes, the lack of statistical significance in the differences between means might be disregarded, in that the values of the means themselves could be incorporated into a scale. This area of graph evaluation might benefit from more study before a decision about procedure is made. Certainly the assessment of neural patterns of reorganization and reorientation toward a new task is important enough to merit further examination.

Table 16, deals with the children's performance in the area examined by Table 15, for adults. Superficially there appears to be only one area of difference in the pattern of the two tables. The difference between the means of identity of interval scores for the eyes open and eyes closed performances of the dominant hand are highly significant for children. In adult scores the difference was non-significant. Otherwise the pattern of the two tables appears the same.

A more detailed analysis however suggests that the two tables show several other important variations. In the area of probability the children's scores approach significance twice, with levels of confidence in the .09 and .11 range. This does not happen with adult scores. Both sections of the sample were able to reorientate toward a new task more efficiently with the dominant hand than with the non-dominant. This is disclosed by an examination of the means. But the means also disclose that whereas, with either hand, children's performance consistently improved to a marked degree, when eyes

TABLE 16

TESTS OF SIGNIFICANCE FOR

DIFFERENCES BETWEEN MEANS

OF IDENTITY OF INTERVAL SCORES FOR

CHILDREN ON TASK II [a]

Task	Means	t Values	Probability	Sig. [b]
EOD [c]	0.38			
		0.50	0.62	N.S.
EOND	0.31			
ECD	0.83			
		1.73	0.09	N.S.
ECND	0.55			
EOD	0.38			
		3.43	0.00	**
ECD	0.83			
EOND	0.31			
		1.63	0.11	N.S.
ECND	0.55			

[a] Degrees of freedom = 1,53

[b] ** = $p < .01$ = highly significant
  * = $p < .05$ = significant

[c] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

were closed, adults showed only a minute improvement with the dominant hand, when eyes were closed, and a similarly small deterioration, with the non-dominant hand, when the role of the eyes was eliminated.

The role of the level of development that has been reached in the establishment of definite lateral dominance appears to have influenced the scores in this area of the graphs. Adults appear to have long since reached a maximal level and to have been perfecting the processes through many years of practice. The scores of the children suggests that there is still a great deal of ambidexterity present. When the eyes are open, both adults and children experience a downgrading of the dominant hand, presumably as a result of the need to coordinate component visual-motor processes at the level of the least efficient one. The disparity between levels of components, however, is vastly greater for children, than it is for adults, as an examination of the means discloses. Once again, the validity of assessing motor development from an act involving visual participation, such as that required in a "copying test", is called into question.

Summary of Tables 9 to 16, Inclusive.

These tables produced firm evidence that the research device was capable of detecting significant differences in the levels of motor performance for both adults and children. In areas in which it did not detect significant differences there are valid grounds for accepting the findings that, within the limits of precision demanded from a mass screening device, there were in fact, no significant differences.

These findings, then, can be taken to uphold the first hypothesis that when tasks were repeated by the same person, under conditions that were minimally different, the research device would be able to detect any

TABLE 17

SUMMARY OF TABLES 3 TO 16 INCLUSIVE

SHOWING AREAS

CONTAINING SIGNIFICANT DIFFERENCES BETWEEN MEANS

	ADULTS								CHILDREN					
	Task I		Task II						Task II					
Criterion	Sp	Pr	Sp	Pr	AMM	AMR	PI	II	Sp	Pr	AMM	AMR	PI	II
Table No.	3	4	5	7	9	11	13	15	6	8	10	12	14	16
EOD cf [b] EOND	**	**	**	**	*	**	**	NS	NS	**	**	*	NS	NS
ECD cf ECND	**	**	**	**	**	*	**	NS	NS	**	**	NS	NS	NS
EOD cf ECD	NS	NS	NS	NS	NS	NS	NS	NS	**	**	**	*	NS	**
EOND cf ECND	*	NS	*	NS	NS	NS	NS	NS	**	**	**	**	NS	NS

** = $p < .01$ = highly significant
 * = $p < .05$ = significant

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

significant differences that were present.

The patterns of results of the individual tables showed that the device was also able to detect differences between the performance of the sample of nursery school children and that of the adult sample. In those corresponding areas in which one of the samples was seen to possess significant differences while the other sample contained no such differences, it can also be said that the second hypothesis was upheld. The device detected between-person differences when the same task was performed under the same conditions by different people. However, since the two samples represent the extreme ends of the developmental scale, as far as the writing act is concerned, this ability to detect significant differences can only be considered as an indication of a trend, rather than as complete validation of the second hypothesis. It is for this reason that the second hypothesis has, to this point, only been considered as partially upheld.

Tables 18 to 31 Inclusive

Tables 18 to 31, inclusive, tabulate the correlation coefficients showing the relationships between the criteria by which the graphs were quantified and the classificatory variables which applied to the sample.

It was noted, during discussion of the research design, that these classificatory variables were derived from a questionnaire, after the sample had been selected. There was no attempt made to validate the subject's answers by standardized tests. It is therefore not possible to extend any of the findings to the general population.

The tables are included merely as an indication of possible trends or as a suggestion that many of the areas offer fields for further study.

The high level of significance between many of the classificatory variables and the criteria does suggest that the research device is capable of detecting between-people differences. Had these differences been based on reliable tests, rather than the estimates of individuals, on a questionnaire, the second hypothesis might have been considered upheld. As it is, acceptance of this hypothesis must remain tentative. For this study, at this time, it is supported. A more scientific design could very well contradict this conclusion.

In order that the classificatory variables may be understood from the abbreviated form in which they are listed in the tables, the following is inserted at this point:

Age:	Children were listed according to their age in months (61 to 72 months, inclusive).
Age Group:	Adults were grouped 1. Under 20 years 2. 20 to 30 years 3. 30 to 40 years 4. Over 40 years
Draw-a-Man Score:	The children's drawing of a man was scored according to the Harris modification of the Goodenough scale and the raw score was entered.
Educational Level:	Adults were grouped 1. Graduate or post graduate student 2. Undergraduate student 3. Non-university
Half Days per Week:	The children attended either three or five hald days a week. The raw data was inserted: either a 3 or a 5.
Laterality Class:	All subjects were grouped 1. Homolateral 2. Ipsolateral
Music Group:	Adults were grouped 1. Musician 2. Non-musician

Number of Instruments: The estimate of the subject was entered intact.

Sex: All subjects were grouped
1. Male
2. Female

Typing Group: Adults were grouped
1. Non typist
2. Non-touch typist
3. Touch typist

Typing-Music Group: Adults were grouped
1. Neither typist nor musician
2. Typist only
3. Musician only
4. Both typist and musician

Years in Nursery School: Children were grouped
1. First year of nursery school attendance
2. Second year of nursery school attendance

Years of Formal Training: The number of years that the subject reported taking formal music lessons was entered intact.

Years of Playing: The number of years that the subject reported were entered intact.

Years of Typing: The estimate of the subject was entered intact.

TABLE 18

CORRELATION COEFFICIENTS
SHOWING RELATIONSHIPS BETWEEN
SPEED AND CLASSIFICATORY VARIABLES
FOR ADULTS ON TASK I [a]

Classificatory variable	Speed EOD	Speed EOND	Speed ECD	Speed ECND [b]
SEX	0.0661	-0.1994	-0.0371	-0.0365
AGE GROUP	0.1761	0.0935	-0.0425	'0.2286
EDUCATIONAL LEVEL	*0.2586	0.0596	-0.1213	0.1569
TYPING GROUP	-0.0810	-0.0027	0.1726	-0.0076
YEARS OF TYPING	-0.1809	-0.0913	0.0018	-0.0318
MUSIC GROUP	-0.1155	0.0400	*-0.2966	0.0965
NUMBER OF INSTRUMENTS	-0.0658	-0.0097	0.0991	*-0.2707
YEARS OF FORMAL TRAINING	-0.0367	0.0564	-0.1050	-0.0266
YEARS OF PLAYING	-0.0664	0.0500	-0.0550	-0.1529
TYPING-MUSIC GROUP	-0.1609	0.1329	0.0146	-0.1488
LATERALITY CLASS	0.0000	0.0000	0.0000	0.0000

[a] Degrees of freedom = 1,53

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 19

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

PRODUCTIVITY AND CLASSIFICATORY VARIABLES

FOR ADULTS ON TASK I [a]

Classificatory variable	Prod. EOD	Prod. EOND	Prod. ECD	Prod. ECND [b]
SEX	0.0127	-0.2117	-0.0346	-0.0380
AGE GROUP	'-0.2368	0.1613	-0.0668	0.0841
EDUCATIONAL LEBEL	0.0443	0.0992	*0.2599	*0.2817
TYPING GROUP	-0.1656	0.0716	-0.0581	-0.2034
YEARS OF TYPING	0.0065	-0.0712	-0.0328	'-0.2492
MUSIC GROUP	-0.0893	-0.0722	0.0437	-0.1414
NUMBER OF INSTRUMENTS	-0.0872	-0.0447	-0.0636	-0.0464
YEARS OF FORMAL TRAINING	0.0781	-0.0865	0.0647	*-0.3200
YEARS OF PLAYING	0.0345	-0.1047	0.0327	*-0.3313
TYPING-MUSIC GROUP	-0.0385	-0.0122	-0.1555	0.0276
LATERALITY CLASS	0.0000	0.0000	0.0000	0.0000

[a] Degrees of freedom = 1,53

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 20

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

SPEED AND CLASSIFICATORY VARIABLES

FOR ADULTS ON TASK II [a]

Classificatory variable	Speed EOD	Speed EOND	Speed ECD	Speed ECND [b]
SEX	0.0963	'0.2259	*0.2687	0.1709
AGE GROUP	0.0557	-0.0162	-0.0467	-0.0519
EDUCATIONAL LEGEL	0.1326	0.0722	0.1838	0.0024
TYPING GROUP	0.1854	0.0459	0.1374	0.0114
YEARS OF TYPING	0.1405	-0.0038	0.0051	0.0366
MUSIC GROUP	-0.1063	-0.0778	0.0204	0.0475
NUMBER OF INSTRUMENTS	-0.1643	-0.0939	-0.0710	-0.0346
YEARS OF FORMAL TRAINING	'-0.2168	0.0958	0.0377	0.0485
YEARS OF PLAYING	-0.2114	-0.0488	0.0465	0.1506
TYPING-MUSIC GROUP	-0.0412	-0.0595	0.0727	0.0400
LATERALITY CLASS	-0.0177	-0.0808	-0.0457	-0.1428

[a] Degrees of freedom = 1,53

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 21

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

PRODUCTIVITY AND CLASSIFICATORY VARIABLES

FOR ADULTS ON TASK II [a]

Classificatory variable	Prod. EOD	Prod. EOND	Prod. ECD	Prod. ECND [b]
SEX	0.0889	-0.0651	-0.1381	-0.0040
AGE GROUP	-0.0600	0.1147	0.0555	0.1076
EDUCATIONAL LEVEL	0.2059	-0.0380	-0.0086	0.1305
TYPING GROUP	**-0.3435	-0.1540	**-0.3374	**-0.3353
YEARS OF TYPING	-0.1749	-0.0039	-0.1041	-0.1963
MUSIC GROUP	0.0387	.0.1002	0.0758	0.1852
NUMBER OF INSTRUMENTS	0.1216	0.1092	0.0468	0.0545
YEARS OF FORMAL TRAINING	0.0392	-0.0819	-0.0822	0.0551
YEARS OF PLAYING	-0.0199	0.1258	0.0950	0.0900
TYPING-MUSIC GROUP	-0.1098	0.0054	-0.0493	0.0250
LATERALITY CLASS	-0.0975	-0.0294	-0.1203	-0.1248

[a] Degree of freedom = 1,53

** = $p < .01$ = highly significant
 * = $p < .05$ = significant
 ' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, npn-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 22

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

AMPLITUDE MAXIMA MEANS & CLASSIFICATORY VARIABLES

FOR ADULTS ON TASK II [a]

Classificatory variable	A.M.M. EOD	A.M.M. EOND	A.M.M. ECD	A.M.M. ECND [b]
SEX	0.1344	-0.0642	0.0622	0.0267
AGE GROUP	-0.0672	0.0923	0.1160	0.1376
EDUCATIONAL LEVEL	0.1045	0.0725	0.0739	0.0546
TYPING GROUP	-0.1156	-0.1145	*-0.2912	-0.2134
YEARS OF TYPING	-0.1008	0.0293	-0.1237	0.0175
MUSIC GROUP	0.0768	0.0764	0.0335	'0.2267
NUMBER OF INSTRUMENTS	-0.0085	0.0368	0.0156	0.0816
YEARS OF FORMAL TRAINING	0.0565	-0.0089	-0.1023	0.0841
YEARS OF PLAYING	-0.0349	0.0022	-0.008	0.1836
TYPING-MUSIC GROUP	-0.0042	-0.0063	-0.0854	0.1083
LATERALITY CLASS	0.0869	0.0414	-0.1516	-0.1233

[a] Degrees of freedom = 1,53

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 23

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

AMPLITUDE MAXIMA RANGE & CLASSIFICATORY VARIABLES

FOR ADULTS ON TASK II [a]

Classificatory variable	A.M.R. EOD	A.M.R. EOND	A.M.R. EOD	A.M.R. EOND [b]
SEX	0.0272	0.0350	-0.0622	-0.0658
AGE GROUP	0.1564	0.0273	0.1444	'0.2255
EDUCATIONAL LEVEL	0.1084	-0.0304	-0.0803	-0.1329
TYPING GROUP	-0.0818	0.1600	-0.1893	-0.0386
YEARS OF TYPING	-0.1073	0.1740	-0.1088	*0.2794
MUSIC GROUP	'-0.2352	0.0856	-0.1302	0.1739
NUMBER OF INSTRUMENTS	-0.1315	0.0087	0.0356	0.0187
YEARS OF FORMAL TRAINING	-0.1812	-0.0477	-0.1466	0.0797
YEARS OF PLAYING	-0.1938	0.1112	-0.0050	'0.2396
TYPING-MUSIC GROUP	'-0.2272	0.1307	-0.1800	0.1584
LATERALITY CLASS	0.0257	0.0053	-0.0420	-0.1766

[a] Degrees of freedom = 1,53

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 24

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

IDENTITY OF PATTERN SCORE & CLASSIFICATORY VARIABLES

FOR ADULTS ON TASK II [a]

Classificatory variable	Pat.Sc. EOD	Pat.Sc. EOND	Pat.Sc. ECD	Pat.Sc. ECND [b]
SEX	-0.0027	-0.0850	-0.1698	0.0648
AGE GROUP	'0.2171	-0.0871	-0.0215	'-0.2201
EDUCATIONAL LEVEL	-0.1883	*-0.2568	*-0.2797	-0.0170
TYPING GROUP	0.0988	'-0.2244	-0.1678	0.0350
YEARS OF TYPING	0.1415	0.0012	-0.1277	0.0163
MUSIC GROUP	-0.0122	0.0564	0.0000	-0.1313
NUMBER OF INSTRUMENTS	0.0845	0.1247	0.1830	0.0942
YEARS OF FORMAL TRAINING	0.0293	0.0417	0.1398	0.0287
YEARS OF PLAYING	0.0222	0.0997	0.1002	'-0.2472
TYPING-MUSIC GROUP	0.0499	0.0020	-0.0467	-0.0835
LATERALITY CLASS	-0.0511	-0.1318	0.1290	-0.0212

[a] Degrees of freedom = 1,53

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 25

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

INTERVAL IDENTITY SCORE & CLASSIFICATORY VARIABLES

FOR ADULTS ON TASK II [a]

Classificatory variable	Int.Sc. EOD	Int.Sc. EOND	Int.Sc. ECD	Int.Sc. ECND [b]
SEX	**-0.3668	'-0.2194	-0.1783	-0.1685
AGE GROUP	-0.0071	0.0000	0.0329	-0.0423
EDUCATIONAL LEVEL	-0.1844	-0.1079	-0.0437	*-0.3266
TYPING GROUP	-0.1025	'-0.2367	0.0110	-0.1793
YEARS OF TYPING	0.0517	0.0724	-0.0292	-0.0067
MUSIC GROUP	0.0000	0.0833	-0.0533	-0.0282
NUMBER OF INSTRUMENTS	0.1059	0.1793	-0.1274	0.0034
YEARS OF FORMAL TRAINING	0.1232	0.0327	-0.0535	0.1416
YEARS OF PLAYING	0.1356	0.0029	-0.0021	-0.0392
TYPING-MUSIC GROUP	-0.0057	-0.0353	-0.0414	-0.0697
LATERALITY CLASS	0.1429	0.0000	0.1890	0.0318

[a] Degrees of freedom = 1,53

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 26

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

SPEED AND CLASSIFICATORY VARIABLES

FOR CHILDREN ON TASK II [a]

Classificatory variable	Speed EOD	Speed EOND	Speed ECD	Speed ECND [b]
SEX	'-0.2505	0.0259	-0.1992	-0.0730
AGE	'-0.2192	-0.0634	0.0741	-0.1312
YEARS IN NURSERY SCHOOL	0.2090	0.0999	-0.0748	-0.0247
½ DAYS PER WEEK	-0.1312	'-0.2250	-0.1185	0.0114
LATERALITY CLASS	0.0780	0.0503	0.1828	0.1799
DRAW-A-MAN SCORE	-0.1610	*-0.3345	-0.1945	*-0.2618

[a] Degrees of freedom = 1,57

** = $p < .01$ = highly significant
 * = $p < .05$ = significant
 ' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 27

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

PRODUCTIVITY AND CLASSIFICATORY VARIABLES

FOR CHILDREN ON TASK II [a]

Classificatory variable	Prod. EOD	Prod. EOND	Prod. ECD	Prod. ECND [b]
SEX	0.2050	0.0070	0.0688	0.0454
AGE	0.2138	0.1283	-0.0278	*0.2611
YEARS IN NURSERY SCHOOL	'-0.2436	**-0.3594	0.0578	-0.0747
½ DAYS PER WEEK	0.0444	0.1909	0.1341	0.0966
LATERALITY CLASS	0.1272	0.1000	-0.0572	0.0545
DRAW-A-MAN SCORE	-0.0151	0.0642	-0.0504	0.1249

[a] Degrees of Freedom = 1,57

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 28

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

AMPLITUDE MAXIMA MEANS & CLASSIFICATORY VARIABLES

FOR CHILDREN ON TASK II [a]

Classificatory variables	A.M.M. EOD	A.M.M. EOND	A.M.M. ECD	A.M.M. ECND [b]
SEX	0.1113	-0.1139	0.0577	0.0954
AGE	'0.2121	0.1696	-0.0145	*0.2855
YEARS IN NURSERY SCHOOL	-0.0489	'-0.2135	0.1527	-0.0389
½ DAYS PER WEEK	0.1036	*0.2745	0.0722	0.0644
LATERALITY CLASS	0.1058	0.0642	-0.0902	0.0417
DRAW-A-MAN SCORE	0.0506	0.0908	-0.1833	0.0208

[a] Degrees of freedom = 1,57

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 29

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

AMPLITUDE MAXIMA RANGE & CLASSIFICATORY VARIABLES

FOR CHILDREN ON TASK II [a]

Classificatory variable	A.M.R. EOD	A.M.R. EOND	A.M.R. ECD	A.M.R. ECND
SEX	-0.0754	-0.1741	'-0.2334	0.1053
AGE	-0.0692	0.0082	**-0.3561	0.1644
YEARS IN NURSERY SCHOOL	-0.0566	-0.2080	0.1319	-0.0725
½ DAYS PER WEEK	0.0281	-0.1005	-0.1440	-0.0063
LATERALITY CLASS	0.2057	0.1772	-0.0073	-0.1189
DRAW-A-MAN SCORE	0.0852	0.0302	0.0974	-0.1228

[a] Degrees of freedom = 1,57

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 30

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

IDENTITY OF PATTERN SCORE & CLASSIFICATORY VARIABLES

FOR CHILDREN ON TASK II [a]

Classificatory variable	Pat.Sc. EOD	Pat.Sc. EOND	Pat.Sc. ECD	Pat.Sc. ECND [b]
SEX	0.1102	-0.0352	0.0660	0.1148
AGE	-0.0777	**-0.3363	*-0.3011	'-0.2329
YEARS IN NURSERY SCHOOL	'-0.2267	0.1849	0.1234	'-0.2417
½ DAYS PER WEEK	0.0490	-0.0824	0.1402	-0.1397
LATERALITY CLASS	0.0114	-0.1206	'0.2246	-0.1298
DRAW-A-MAN SCORE	0.2016	0.1874	-0.0536	0.0113

[a] Degrees of freedom = 1,57

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

TABLE 31

CORRELATION COEFFICIENTS

SHOWING RELATIONSHIPS BETWEEN

INTERVAL IDENTITY SCORE & CLASSIFICATORY VARIABLES

FOR CHILDREN ON TASK II [a]

Classificatory variable	Int.Sc. EOD	Int.Sc. EOND	Int.Sc. ECD	Int.Sc. ECND [b]
SEX	'0.2199	0.0476	0.0000	0.0772
AGE	0.0535	0.1012	0.1362	0.0735
YEARS IN NURSERY SCHOOL	0.0034	-0.0551	0.1269	-0.1369
½ DAYS PER WEEK	0.1843	0.1536	0.0919	-0.0045
LATERALITY CLASS	-0.0988	-0.0181	0.0581	-0.1120
DRAW-A-MAN SCORE	0.1008	'0.2163	0.0753	0.1455

[a] Degrees of freedom = 1,57

** = $p < .01$ = highly significant
* = $p < .05$ = significant
' = $p < .10$ = approaching significance

[b] EOD = eyes open, dominant hand
EOND = eyes open, non-dominant hand
ECD = eyes closed, dominant hand
ECND = eyes closed, non-dominant hand

Summary of Chapter IV

The statistical analysis of the quantified evaluations of graphs produced on the research device were discussed in this chapter. Tables showing the result of tests of significance for differences between means of the criteria for adults and children were prepared and discussed. On the basis of the findings in these tables it was disclosed that the research device was capable of detecting significant differences when the same task was repeated by the same person under conditions that were minimally different. These findings upheld the first hypothesis.

The same tables also produced evidence that there were significant differences between the patterns of adult and child performances. Since, however, these sections of the sample are recognized as representing the two extremes in a developmental scale of motor control, it was felt that the second hypothesis could not be considered to be completely upheld, without further study. It would be necessary to derive evidence that more precise discrimination was possible with the device.

A second group of tables listing the correlation coefficients that showed the relationships between the criteria and the classificatory variables that applied to the sample, appeared to provide the necessary confirmation.

But once more, acceptance of such evidence had to be tempered with extreme caution. The classificatory variables were not based on standardized tests, and in many cases consisted of subjects' estimates. Where data was objective (age, sex, educational level, laterality class) there were many relationships that were highly significant, significant or approaching

significance. On the basis of these results, the second hypothesis, that the device could discriminate between the performance of the same task by different people, could also be considered to be upheld.

CHAPTER V

FINDINGS AND CONCLUSIONS

The Research Device

The major objective of this study was to design, build and evaluate a device that might be used as a mass screening instrument for children entering school for the first time. The purpose of the device was to isolate and measure the degree of control of manual-digital fine muscles that such children could bring to the execution of a writing task.

A device was built that satisfied the criteria that had been decided upon: it was both inexpensive and simple. Tasks to be executed upon it were selected on the basis of research into the developmental process of children and into previous tasks used by previous researchers. These tasks were simple and they did not take much time to execute.

Quantification of the evaluation of the graphs produced during execution of the tasks was a laborious process and very time-consuming. Six criteria were selected on the basis of research into the characteristics of a skilled fine motor performance as well as into the criteria used by previous studies. Each graph was subjected to six measurements, some of which involved the production by the researcher of special templates as well as special formulae to enable the graph evaluations to be quantified. The most laborious procedure involved the measurement of the actual length of the graph line. For this purpose the graph had to be enlarged five times by projection in an opaque projector. The image was traced with chalk, then measured with an inch-counter (mile-o-meter) at that point, because the

original graph was too small for accurate measurement by such an instrument. The resultant measurement was then divided by five.

Although enlargement by projection and subsequend division of the measurement by five, tends to reduce the margin of error in measurement, this procedure could become very burdensome if many subjects were tested. Each subject produces at least four graphs, and each graph has to be measured at least twice, to insure accuracy.

Nevertheless, on the basis of the statistical analysis of the quantified data, the device was found to be efficient. It was tested by two hypotheses. The first hypothesis that it would be capable of detecting significant differences when the same task was carried out by the same person under conditions that were minimally different, was completely upheld. On the basis of the support for this hypothesis it appears to be valuable to proceed with the testing of large numbers of children who are entering school for the first time, in order to develop a norm against which the performance of an individual child could be evaluated.

The support for the second hypothesis was not complete. This can be attributed to the caution necessary in the acceptance of results from data that has not been objectively obtained by a standardized test of some type. In this study some of the classificatory variables were based on the estimates of subjects made in a questionnaire. On the other hand, data based on such facts as sex, age, lateral preference and educational level did produce evidence that the device was capable of detecting significant differences in the same task when it was executed under the same conditions by different people.

These findings reinforce the conclusion made on the basis of the

support for the first hypothesis. A further study devoted to the development of norms of manual-digital fine motor function for mass screening procedures, appears to be indicated as the next step toward providing more discrete and precise evaluation of a child's learning potential, when he enters school.

Other Findings

Apart from measuring with the research device the current performance of the subjects, the data that was analyzed produced other valuable insights.

The two sections of the sample represented the two extremes in the developmental scale of graphomotor skills. The adult sample was mature, the child sample was naive. A comparison of patterns of performance indicated the directional trend that maturation would take.

In the matter of speed of performance, for example, the process of maturation appears to completely eliminate differences in the performance of the dominant hand between eyes-open and eyes-closed conditions. On the other hand, maturity appears to strengthen lateral dominance so that there are significant differences in speed when the two hands are compared, no matter what the visual condition of the performance is. How much of this difference is due to factors of practice, once laterality is established, might make an interesting study.

Another interesting observation that resulted from analysis of the data seems to indicate that the ambidexterity of childhood must be completely eliminated before the graph patterns that indicate smooth, coordinated, rhythmic motor responses in a writing act, can be produced. Tracing this process might also be a valuable contribution to the understanding of the role of lateral dominance and its influence.

There was also a suggestion of the sequence in which component skills that constitute a coordinated motor performance are developed.

On the basis of evidence in the tables that related to interval identity scores, pattern identity scores, speed scores and amplitude maxima scores, it appears that facility in reorientation of motor responses between tasks is the area in which the earliest and greatest transfer from other experience is made. Speed, when not inhibited by visual monitoring, also appears to rely to some extent on transfer from similar experiences. Pattern identity and amplitude maxima scores, however, indicate that the conclusions of past research about the specificity of motor skills is supported by the results of the current study as well.

It is also interesting to speculate on what seems to be implied by the analysis of the interval identity scores. It appears that the ability to regroup or reorientate quickly toward the initiation of a new segment of a motor task is a generalized function in the neuromotor system, rather than a specifically developed response to a given situation. Could this be part of the general motor ability factor that some researchers mention? How is this ability to reorientate, related to intelligence? Does it influence the eventual level of perfection that a motor skill may reach? These, too, might be valuable areas to investigate.

The most obvious finding of the study is not a novel one. Practice is necessary to mature and perfect a graphomotor skill, just as it has been found necessary in the perfecting of any other motor skill.

The most significant of the secondary findings based on the results of this study also appears to be an obvious one. Comparison of eyes-open and eyes-closed performances reveals that when sensory processes are

coordinated the resultant level of performance takes place on the level of the weakest component of the process. Consideration of the implications of this apparently obvious conclusion, however, reveals its importance in the education of a child, with especial emphasis on the teaching of reading.

Implications for Reading

A copying task of the type demanded by first grade readiness tests calls upon the child to coordinate visual, perceptual, intellectual-experiential and motor processes in the production of a response. If this response is produced on the level of the weakest component process, it is necessary to identify that component for purposes of remediation. Including the research device of this study, it is possible to do so.

The orthorator or the telebinocular can be used to discover whether the weakness is in the area of visual acuity. The Frostig (1963) tests can be employed to determine the state of visual perception. The McCarthy and Kirk (1961) psycholinguistic tests can be administered to assess the experiential and language background of the child and any of the better intelligence tests can provide an insight into his intellectual functioning. If manual-digital fine motor development is also evaluated through the use of a mass screening device the major components of "eye-hand coordination" will have been examined.

Remediation, once a weakness has been identified in any component process, can be specifically directed at strengthening the area or eliminating the problem. The fitting of eye glasses, the provision of training exercises or opportunities to extend experience can all be arranged.

If the problem is not found in any of the component processes, the

child's ability to coordinate the processes must become suspect. Early diagnosis of this disability is of major importance.

If reading instruction is begun before remediation has minimized the influence of underdeveloped areas, there is grave risk of doing permanent injury to a child's scholastic potential. Such injury also entails damage to his personality and consequently to his ability to function normally in society.

A child has the right to be safeguarded against such possibilities. When safeguarding involves only the use of available devices and techniques, society had the right to expect the school to use them.

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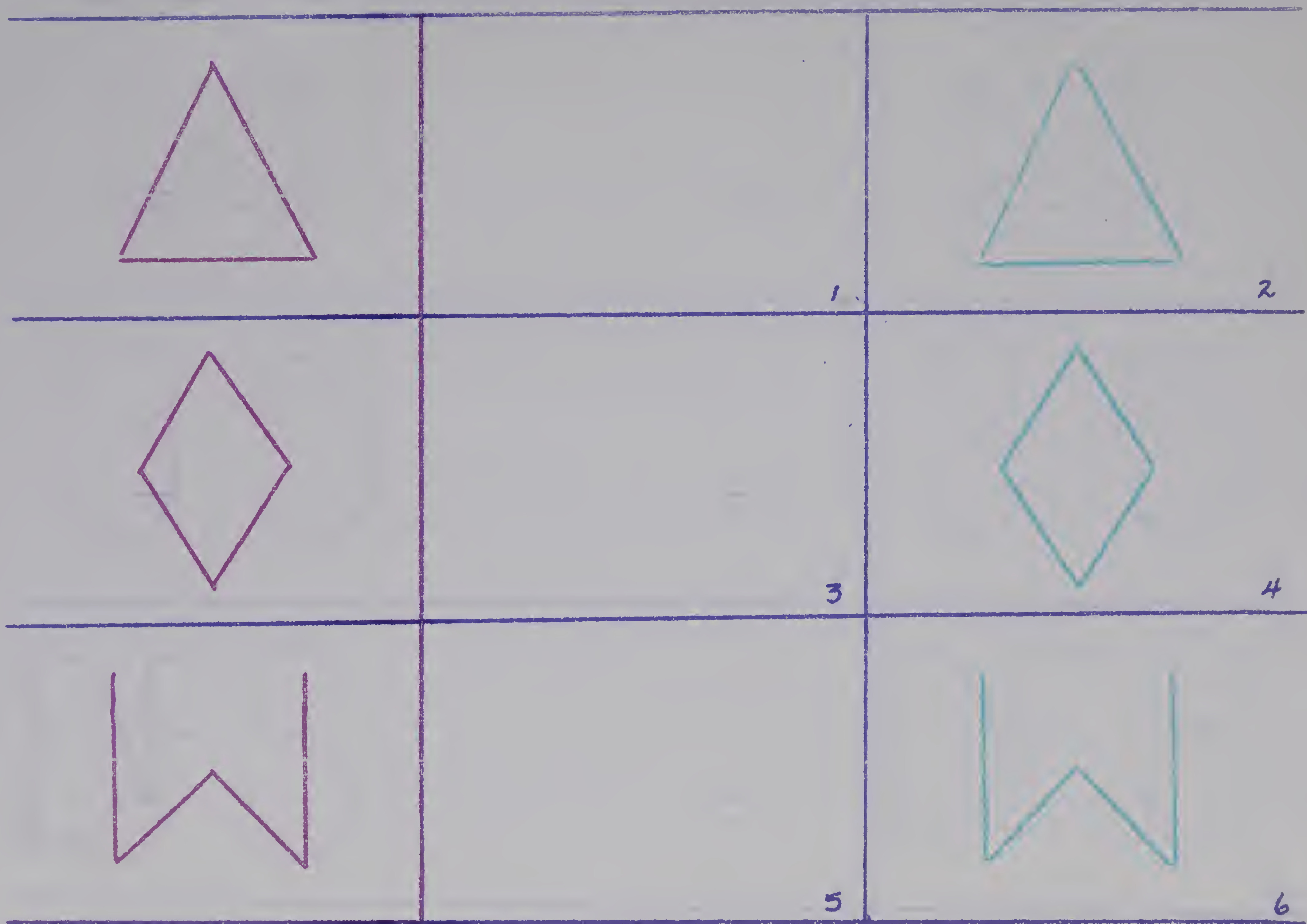
APPENDIX



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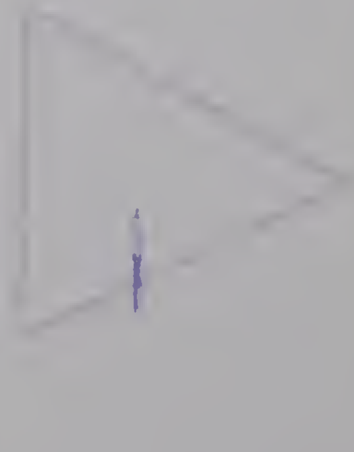

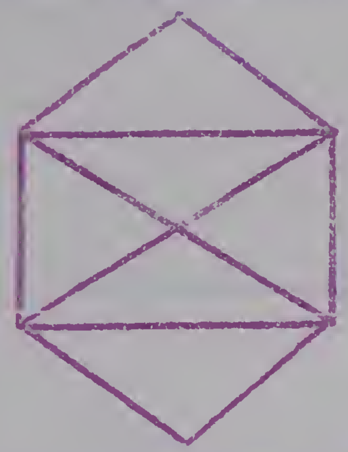	7	 8
35	9	35 10
DFS	11	DFS 12

fox	13	fox 14
jumps	15	jumps 16
fox	17	fox 18
jumps	19	jumps 20

NAME ________________________ I.D. # ____________ SEX M F (circle One)

ADDRESS ________________________ Phone ________

SCHOOL ________________________ Grade ________

AGE: (School Children) ________ yrs. ______ Mos. Birthdate __________

AGE: (Adults) - Under 20 _____, 20 to 30 ______, 30 to 40 _____, Over 40 _____

OCCUPATION ________________________

LATERALITY

1. With which hand do you normaly write? ____________
2. Dominant eye ____________
3. Did you always prefer to use this hand? ____________
4. At what age (if changed) did you start using this hand to write? ________ ______________ Why? ________________________

MUSIC

1. Do you play any musical instrument(s)? ____________
2. Please list instruments ____________ ____________
   ____________ ____________
   ____________ ____________
3. How many years have you been playing? ____________
4. How many years of formal musical training have you had? ____________
5. Approximately how many years per week have you averaged in practice? _____

TYPING

1. Have you learned touch-typing? ____________
2. How many years have you been typing? ____________
3. Approximately how many hour per week do you spend typing? ____________
4. What is your approximate typing speed? ____________

OTHER

1. Do you use any other machine or instrument that requires the use of fingers of both hands? ____________
2. Please list instrument/machines ____________ ____________
   ____________ ____________
   ____________ ____________
3. Approximately how many hours per week do you use the above? ________